DEMONSTRATION DATA REPORT

EM61 MkII Transect Demonstration at Former Camp Beale Technology Demonstration Data Report

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NOVA Research, Inc.

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14. ABSTRACT

As part of the ESTCP WAA Pilot Project, Nova Research, Inc. demonstrated a data collection and analysis methodology to support the rapid delineation of areas of UXO contamination within a larger site. Electromagnetic Induction (EMI) data were collected over the demonstration site along planned transects provided by PNNL in cooperation with SNL and the ESTCP Program Office. These transects were designed based on available archive information to insure that areas of interest matching the design criteria would be sampled with a statistically defensible probability of detection. These data were analyzed to extract anomaly locations and a measure of the anomaly magnitude using an automated anomaly detection methodology. A vehicular-towed array system of EM61 MkIIs (NRL’s MTADS) was deployed for a period of 5 weeks. The system covered 225 lane kilometers of the site and identified 5,779 anomalies. A man-portable EM61 MkII system was concurrently deployed for a period of 6 weeks. The MP EM system covered 178 lane kilometers of the site and identified 3,631 anomalies.

15. SUBJECT TERMS

Wide Area Assessment (WAA), Unexploded Ordnance (UXO), Multi-sensor Towed Array Detection System (MTADS), Electromagnetic Induction (EMI), Transect survey

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Abbreviations Used

Abbreviation	Definition
AFB	Air Force Base
AMTADS	Airborne Multi-sensor Towed Array Detection System
AOI	Area of Interest
APG	Aberdeen Proving Ground
AS	Analytic Signal (nT\m)
ASR	Archives Search Report
ATC	Aberdeen Test Center
BP	Blossom Point
CD-R	Compact Disk - Recordable
COG	course-over-ground
CoC	Certificate of Clearance
CSM	Conceptual Site Model
DAQ	Data Acqusition (System)
DAS	Data Analysis System
DGPS	Differential GPS (meter or sub-meter level)
DoD	Department of Defense
DSB	Defense Science Board
DVD-R	Writable digital versatile disc
EM(I)	ElectroMagnetic (Induction)
ESTCP	Environmental Security Technology Certification Program
FA	False Alarm
FAR	False Alarm Rate
FFT	Fast Fourier Transform
FUDS	Formerly -Used Defense Site
GPS	Global Positioning System
HASP	Health and Safety Plan
Hz	Hertz
IDA	Institute for Defense Analyses
LiDAR	LIght Detection and Ranging
MP	Man-Portable
MRA	Munitions Response Area
MTADS	Multi-sensor Towed Array Detection System
NMEA	National Marine Electronics Association
NRL	Naval Research Laboratory
nT	nanoTesla
PBR	Precision Bombing Range
PBR #2	Pueblo Precision Bombing and Pattern Gunnery Range #2
Pd	Probability of Detection
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
(PTNL,)AVR	Time, Yaw, Tilt, Range for Moving Baseline RTK NMEA-0183 message
(PTNL,)GGK	Time, Position, Position Type, DOP NMEA-0183 message
QA	Quality Assurance

Abbreviations Used (cont.)

Abbreviation	**Definition**
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
ROC	Reciever Operating Characteristic
RTK	Real Time Kinematic
SHERP	Safety, Health, and Emergency Response Plan
SNL	Sandia National Laboratories
SNR	Signal to Noise Ratio
TBD	To Be Determined
UTC	Universal Coordinated Time
UXO	Unexploded Ordnance
VV	Victorville
WAA	Wide Area Assessment
YPG	Yuma Proving Ground
YTC	Yuma Test Center
ZIP (250)	Iomega ZIP disk (250 MB version)

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Glenn Harbaugh and Daniel Steinhurst (P.I.) of Nova Research, Inc., Nagi Khadr, Tom Bell, and Tom Furuya of SAIC, Inc. provided onsite project management and data processing support. Ben Dameron and Daniel Hennessy of NAEVA Geophysics, Inc. conducted the vehicular operations using the MTADS. Brian Neely, Robert Curren, James Hancock, and Li Xiaozhuang of NAEVA Geophysics, Inc. comprised the field team responsible for the collection of the man-portable data. Glenn Harbaugh and Jay Johnson of EOTI, Inc. served as Site Safety Officers during the demonstration and provided EOD escort for the field teams. Randall Stringer and Christopher Sheehy of AeroTek, Inc. provided environmental escort to the field teams. The data processing team also assisted the P.I. in the analysis of the results presented in this report. This work was supported by ESTCP under project MM-0533.

The P.I. would like to thank Andrew Atkinson, Tim Caldwell, and Mark Carroll of the California Department of Fish and Game for their assistance in the planning and execution of this demonstration and for providing a location for our base camp facilities within the Spenceville Wildlife Area. Peter Broderick and Terry Gleason of the US Army Corps of Engineers, Sacramento District also provided valuable assistance in the planning and execution of this demonstration.

ABSTRACT

As part of the Environmental Security Technology Certification Program (ESTCP) Wide Area Assessment (WAA) Pilot Project, Nova Research, Inc. demonstrated a data collection and analysis methodology to support the rapid delineation of UXO contamination within a suspect site. Electromagnetic Induction (EMI) data was collected over the demonstration site along planned transects provided by Pacific Northwest National Laboratories (PNNL) in cooperation with Sandia National Laboratory (SNL) and the ESTCP Program Office. These transects were designed based on available archive information and sound statistical sampling methodologies to insure that the areas of interest (AOIs) matching the design criteria would be sampled with a statistically defensible probability of detection deemed acceptable by the involved stakeholders. These data were analyzed to extract anomaly locations and a measure of the anomaly magnitude using an automated anomaly detection methodology. This information was provided to PNNL, SNL, and the ESTCP Program Office for analysis to rapidly delineate UXO contamination sites such as impact areas and bombing targets. With the rapid pace of the automated process, it was possible to interactively plan and execute additional transects to further resolve features of interest while the survey team was still deployed in the field. A vehicular-towed array system of EM61 MkIIs (NRL's MTADS) was deployed for a period of 5 weeks. The system covered 225

lane kilometers of the site and identified 5,779 anomalies. This corresponds to 0.6% coverage of the site. A man-portable EM61 MkII system was concurrently deployed for a period of 6 weeks. The MP EM system covered 178 lane kilometers of the site and identified 3,631 anomalies. This corresponds to 0.2% coverage of the site, or 0.8% total between the two systems. Two areas found to have few anomalies (<20/acre) based on the transect data were further investigated using the man-portable system. 1.4 acres were surveyed using a total coverage survey style. The data were analyzed to extract anomalies in an analogous manner to the transect data. Additionally, each identified anomaly was subjected to individual analysis using physics-based models. The model results are provided for each anomaly. The total coverage results are consistent with the transect results,

Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys

EM61 MkII Transect Demonstration at Former Camp Beale

Marysville, CA

May - July, 2007

1. Introduction

1.1 Background

The location and cleanup of buried unexploded ordnance (UXO) has been identified as a high priority mission-related environmental requirement of the Department of Defense (DoD). The DoD UXO Response Technology Investment Strategy [1] has identified wide area assessment as one of six technology objectives, with a goal of developing capabilities to perform rapid initial assessment of large areas. The Defense Science Board (DSB) Task Force on UXO (DSB) [2] recently estimated that there are 1400 sites suspected of containing UXO contamination covering approximately 10 million acres in the continental US. By some estimates, as much as 80% of this acreage is quite likely not contaminated with UXO at all. A suite of technologies that can accurately and rapidly delineate the areas on each site that are contaminated from those that are not contaminated would lead to an immediate payback in terms of reducing the acreage that must be carefully examined and potentially cleaned.

The Environmental Security Technology Certification Program (ESTCP) Wide Area Assessment (WAA) Pilot Program consists of a layered suite of technologies deployed as a proof-of-concept demonstration of the DSB's WAA call-to-action. The prototypical WAA site is a large area (10,000's of acres) that may contain isolated areas of concentrated UXO such as aiming points. The top layer consists of (relatively) high-flying sensors (and aircraft) (e.g. orthorectified photography), designed to detect "munitions-related features" such as target rings and craters. The next layer is a helicopter-borne magnetometer array designed to detect subsurface ferrous metal directly. The magnetometer data can be used to locate and define boundaries for targets, aim points, and OB/OD sites. The final layer is a ground survey of portions of the site using a ground-based sensor arrays. In conjunction with statistical transect planning, the ground survey aids in defining target locations and boundaries. Outlined below, we have demonstrated two-such final-layer systems using a) a ground-based, towed EM array system and b) a man-portable EM system.

1.2 Objective of the Demonstration

A data collection and analysis methodology was demonstrated to support the rapid delineation of areas of UXO contamination within a suspect site. Electromagnetic Induction (EMI) data were collected over the demonstration site along planned transects provided by Pacific Northwest National Laboratories (PNNL) in cooperation with the ESTCP Program Office and Sandia National Laboratory (SNL). These transects were designed based on available archive information [for example, 3] and sound statistical sampling methodologies. These data were processed to extract anomaly locations and a measure of the anomaly magnitude using an automated anomaly detection methodology. This information was provided to PNNL, SNL, and the ESTCP Program Office for analysis to rapidly delineate UXO contamination sites such as impact areas and bombing targets. With the rapid pace of the automated process, it was possible to interactively plan and execute additional transects to further resolve features of interest while the survey team was still deployed in the field.

2. Technology Description

2.1 Technology Development and Application

The demonstration was conducted using the Naval Research Laboratory (NRL) Multi-sensor Towed Array Detection System (MTADS) EM61 MkII array and a man-portable EM adjunct. The MTADS was developed with support from ESTCP. The MTADS hardware consists of a low-magnetic-signature vehicle that is used to tow different sensor arrays over large areas (10 - 25 acres / day) to detect buried UXO. The MTADS tow vehicle and magnetometer array are shown in Figure 2-1. Positioning is provided using high performance Real Time Kinematic (RTK) Global Positioning System (GPS) receivers with position accuracies of ~2-5 cm. The positioning technology requires the availability of one or more known first-order survey control points.

Figure 2-1 – MTADS vehicle towing the magnetometer array

2.1.1 MTADS EM61 MkII Array

The EM61 MkII MTADS array is an overlapping array of three pulsed-induction sensors specially modified by Geonics, Ltd. based on their EM61 MkII sensor with 1m x 1m sensor coils. The array configuration is shown schematically in Figure 2-2. The direction of travel for the array is indicated by the black arrows. Sensors #1 (Red) and #3 (Blue) are mounted side by side on the trailer while Sensor #2 (Green) is mounted 8 cm above and 10 cm aft of the other two sensors. Each EM61 MkII sensor is composed of a bottom coil and a top coil separate by fiberglass standoffs. The nominal ride height of the bottom coils is 33.5 cm above the ground and the top coil is mounted 43.5 cm above the bottom coil (bottom of coil to bottom of coil separation). The bottom coil is 5.5 cm tall and the top coil is 2.5 cm tall.

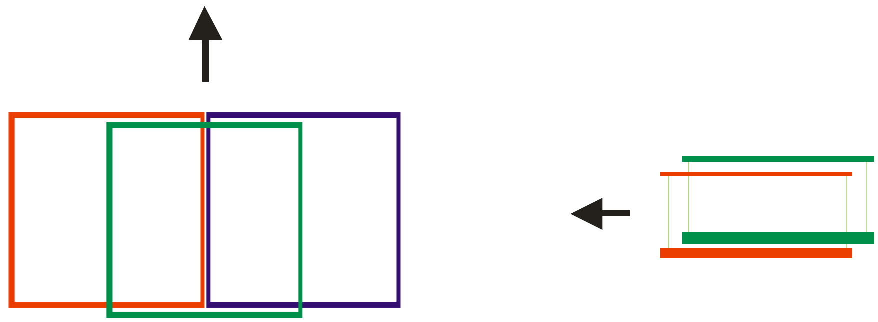

Figure 2-2 – Top and Side Schematic Views of the MTADS EM61 MkII array

The EM61 MkII sensors employed by MTADS have been modified to make them more compatible with vehicular survey speeds and to increase their sensitivity to small objects. The array is operated with the three transmitters synchronized to generate the largest transmit moment. The EM61 MkII sensor can be operated in one of two modes: 1) in 4 time gate mode, in which 4 time gate measurements are made for the bottom coil or 2) in Differential mode, in which 3 time gate measurements are made for the bottom coil, and one is made for the top coil. The timing of the time gates in the MTADS EM61 MkII sensors has been altered from the standard unit and the delay times are given in Table 2-1.

Table 2-1 – NRL EM61 MkII Array Gate Timing Parameters

4 Gate Mode (Bottom Coil)	Delay (μs)	Differential Mode	Delay (μs)
Gate 1	307	Bottom Gate 1	307
Gate 2	508	Top Gate 1	307
Gate 3	738	Bottom Gate 2	738
Gate 4	1000	Bottom Gate 3	1000

The notation S1 for time gate 1 and so forth are used in the remainder of this document. MTADS surveys are typically performed using the Differential mode and this mode was used for this demonstration. While the output data packet format is identical to that of the standard MkII instrument as given in the Geonics EM61 MkII manual [4], there are

some important differences in the interpretation. First, as mentioned above, the time gate delay times have been altered. Second, the byte order for the time gate range factors is Gates 1,4,3,2 rather than the typical 1,2,3,4. The data channels are also presented in the order Gates 1,4,3,2. All conversions from raw counts to response in mV are given as:

$$RESPONSE = \frac{DATA\ x\ 4.8333}{RANGE}$$

The channel-specific *RANGE* values are 100, 10, or 1, as indicated in the Scale Factor parameter in the raw data packet (see Appendix B, Section B.9.1). Nominal survey speed is 3 mph and the sensor readings are recorded at 10 Hz. This results in a down-track sampling of ~15 cm and a cross-track interval of 50 cm.

Individual sensor readings from the EM61 MkII array were located using a RTK GPS system with a single GPS antenna positioned just forward of the EM61 sensor coils. The configuration shown in Figure 2-3 has additional GPS antennae aft of the sensor coils. These antennae and their associated receivers were not used in this demonstration. Position is reported at 10 Hz using a vendor-specific National Marine Electronics Association (NMEA) NMEA-0183 message format (PTNL,GGK or GGK). All GPS measurements are recorded at full RTK precision, ~2-5 cm. All sensor readings are referenced to the GPS 1-PPS output so we are able to fully take advantage of the precision of the GPS measurements.

The individual data streams (sensor readings, GPS positions, times, etc.) are collected by the data acquisition computer, running the MagLogNT software package, and are each recorded in a separate file. These individual data files, which share a root name, consist of three EM61 MkII sensor data files and three GPS files (one containing the GGK sentence, a second containing the UTC time tag, and a third containing the computer time-stamped arrival of the GPS 1-PPS). EM61 MkII data files are recorded in a packed binary format. All GPS files are ASCII format. All these files are transferred to the data analyst using ZIP-250 disks. Refer to Appendix B, Section B.9.1 for the details of the file formats.

Figure 2-3 – MTADS EM61 array pulled by the MTADS tow vehicle

2.1.2 Pilot Guidance System

The GPS positioning information used for data collection is shared with an onboard navigation guidance display and provides real-time navigational information to the operator. The guidance display was originally developed for the airborne adjunct of the MTADS system (AMTADS) [5] and is installed in the vehicle and available for the operator to use. Figure 2-4 shows a screenshot of the guidance display configured for vehicular use.

An integral part of the guidance display is the ability to import a series of planned survey lines (or transects) and to guide the operator to follow these transects. The pilot guidance display can also be used to guide the operator to the survey area and provide immediate feedback on progress and data coverage. The display provides a left-right course correction indicator, an optional altitude indicator for aircraft applications, and color-coded flight swath overlays where the current transect is displayed in red and the other transects are displayed in black for operator reference. The survey course-over-ground (COG) is plotted for the operator in real time on the display. The COG plot is color-coded based on the RTK GPS system status. When fully operational, the COG plot is color-coded green. If the system status is degraded, the COG plot color changes from green to yellow to red (based on severity) to warn the operator and allow for on-the-fly reacquisition of the affected area. Figure 2-4 shows the operator surveying line 30 of a transect plan.

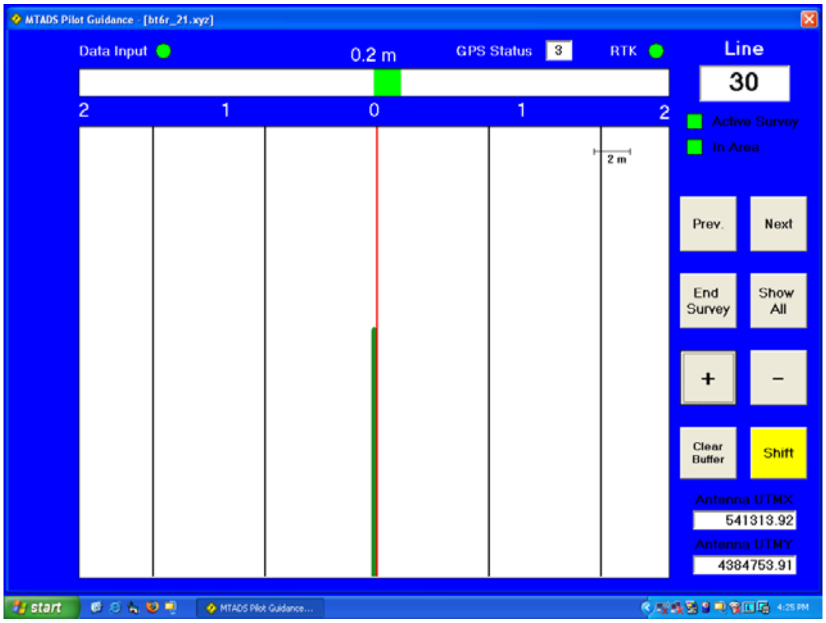

Figure 2-4 – Screenshot of MTADS Pilot Guidance Display

2.1.3 Man-Portable, Litter-Carried EM61 MkII System

A portion of the demonstration was conducted using a man-portable, litter-carried EM61 MkII (MP EM) system developed as an adjunct of the NRL MTADS. The system hardware consists of low-metallic-content components that are used to carry a single standard EM61 MkII metal detector (0.5m x 1m, Geonics, Ltd.) over modest areas (2 acres/day) to detect buried UXO. The complete system as demonstrated at the Victorville WAA demonstration site is shown in Figure 2-5. The sensors are sampled at 10 Hz and surveys are conducted at typical walking speed, ~2 mph (1 m/s). This results in a sampling density of approximately 10 cm down track. For total coverage surveys, a horizontal sensor spacing of 75 cm is used for the 0.5m x 1.0m sensor coil.

Figure 2-5 – Man-portable, litter-carried EM61 MkII sensor system

The standard EM61 MkII is a pulsed-induction sensor which transmits a short electromagnetic pulse (a unipolar rectangular current pulse with a 25% duty cycle) into the Earth. Metallic objects interact with this transmitted field which induces secondary fields in the object. These secondary fields are detected by the detection coils that are collocated with and above the transmit coil. An example is shown in Figure 2-6. The instrument consists of two air-cored 0.5m x 1m coils housed in fiberglass, a backpack containing a battery and processing electronics, and an optional data logging device. The lower coil serves as the transmitter, and main receiver. The upper (receiver only) coil lies 30 cm above the bottom coil. The EM61 MkII can be operated in one of two modes: 1) With 4 time “gates” (216, 366, 660, and 1266 µsec) or 2) in Differential mode, in which 3 time “gates” are measured from the bottom coil (216, 366, 660µsec), and one is measured from the top coil (at 660µsec). Data are recorded using a handheld logger, or alternatively in a PC, using Geonics or custom PC software.

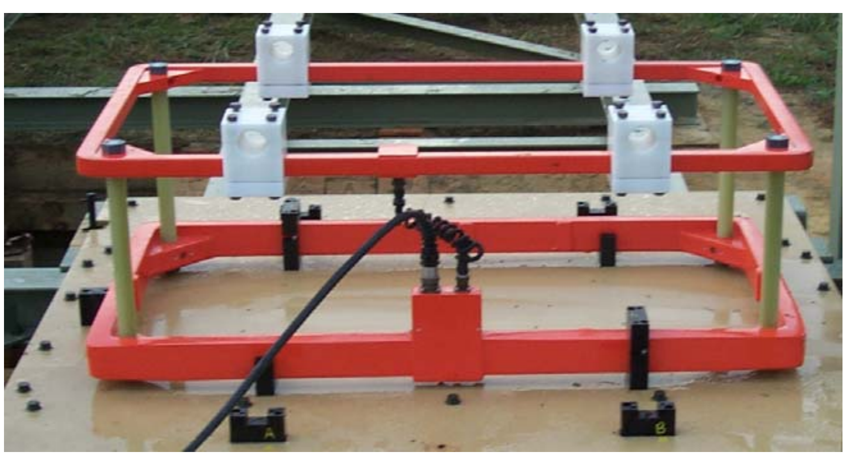

Figure 2-6 – Geonics EM61 MkII coils on a test platform

The sensor position is measured in real-time at 10 Hz with position accuracies of ~2-5 cm using a high performance Real Time Kinematic (RTK) Global Positioning System (GPS) receiver. A sub-meter level, code-phase GPS receiver (Trimble Ag132) was used under dense tree canopies, as required. Within the context of WAA, the lower positional accuracy can be an acceptable tradeoff for enhanced site coverage [6]. All position and sensor data are time-stamped with or referenced to Universal Coordinated Time (UTC) derived from the satellite clocks and recorded by the data acquisition computer (DAQ). The positioning technology requires the availability of one or more known first-order survey control points. The sensor, position, and timing files are downloaded periodically throughout a survey onto removable media and transferred to the data analyst for analysis.

A WAAS-enabled handheld GPS receiver (meter-level, Garmin) was used for navigation during data collection using the built-in point-to-point navigation software. The manufacturer provides software for loading points and routes from a PC into the unit for this purpose.

2.1.4 Data Analysis Methodology

The core data analysis methodology used in this demonstration has been successfully applied in a series of demonstrations over the last two years using a variety of geophysical sensor and positioning systems. Magnetometer arrays have been demonstrated with both RTK and meter-level GPS in towed-array [7,8] and man-portable [6] deployments. Towed-array and man-portable EM61 systems have also been demonstrated [9]. In each case the detailed methodology has been adapted for the particular situation. The two scenarios for this demonstration are discussed in the following sections.

2.1.4.1 EM61 MkII Array Data Analysis Methodology

Each data set is collected using the MagLogNT software package (v2.921b, Geometrics, Inc.). The collected raw data are preprocessed on site for quality assurance purposes using standard MTADS procedures and checks. The data set is comprised of ten separate files, each containing the data from a single system device. See Appendix C for further details about file contents and formats. Each device has a unique data rate. A software package written by NRL examines each file and compares the number of entries to the product (total survey time * data rate). Any discrepancies are flagged for the Data Analyst to address. Next, the data are merged and imported into a single Oasis montaj (v6.4, Geosoft, Inc.) database using custom scripts developed from the original MTADS DAS routines which have been extensively validated. An example of a working screen from Oasis montaj is shown in Figure 2-7. As part of the import process any data corresponding to a sensor outage (or ‘glitch’), a GPS outage, or a vehicle stop / reverse, are defaulted or marked to not be processed further. Defaulted data are not deleted and can be recovered at a later time if so desired. Any long wavelength features such as large scale geology or slow sensor drift are filtered from the data (demedianed).

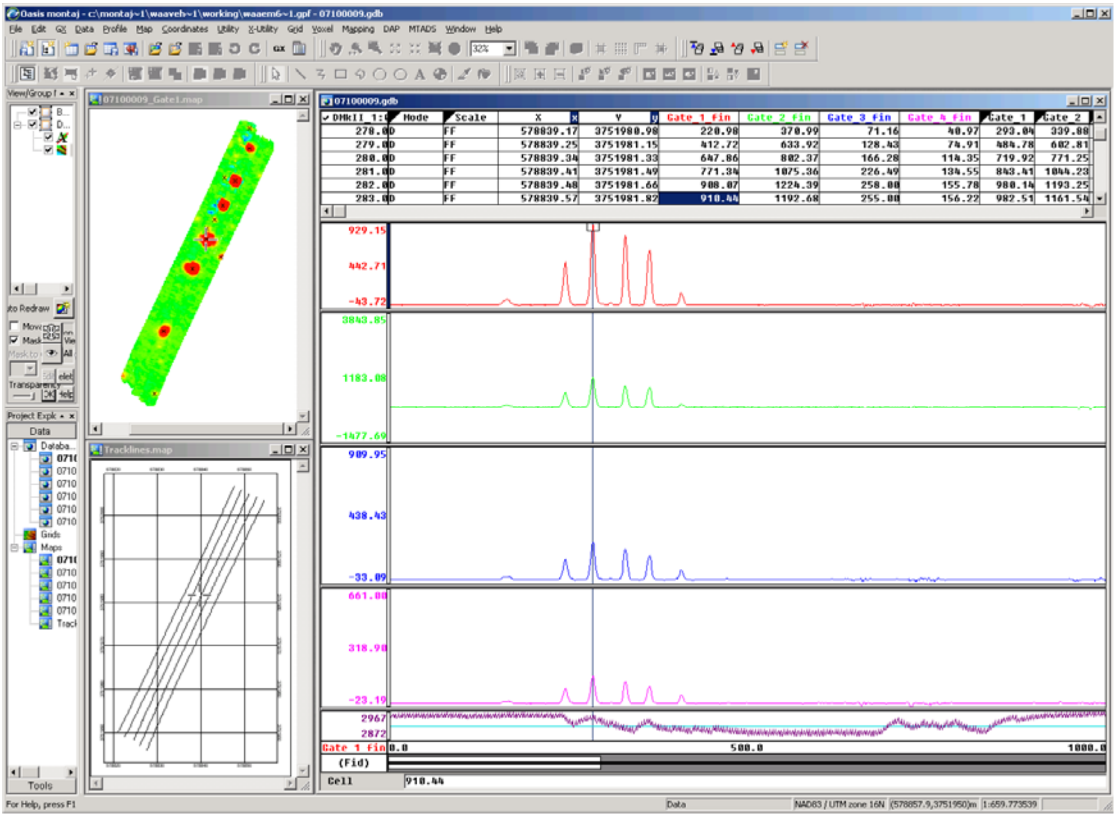

Figure 2-7 – Working screen in Oasis montaj™ of data preprocessing work flow

The EM61 MkII provides data for four time gates and the choice of which time gate to use for anomaly detection can be site-specific. Past experience has shown that for simple detection of anomalies under geologically benign conditions, the earliest time gate is typically the best time gate to use for signal–to-noise reasons. If there are sensor drift problems with S1 data that cannot be removed simply by leveling, a later time gate can be used instead. Data from the second bottom time gate has proven to be useful if geology in the area is apparent in the first time gate data. The first few data sets collected on site are examined and an appropriate time gate is chosen for anomaly selection. The appropriateness of the choice is monitored throughout the demonstration. A built-in feature of Oasis montaj is then used to extract peaks above an empirically determined threshold from the data for the selected sensor time gate. The detected anomaly locations along with the signal magnitude at the peak of the anomaly are provided daily to the ESTCP Program Office, PNNL, and SNL for the previous day's survey results. The down-sampled transect COG (6 – 10 m spacing) are also provided. The data analysis work flow is shown pictorially in Figure 2-8. Additional details on the methodology and its development are available in Reference 10.

For requested total coverage (100%) survey areas, the located demedianed EM data are imported into the UX-Analyze subsystem of Oasis montaj for individual anomaly selection and analysis. UX-Analyze was been developed, in part from the MTADS Data Analysis System (DAS) software, by AETC and Geosoft under ESTCP funding. Based on past experience, the combination of lower coil time gate 1 (Gate 1) and the upper coil

time gate (Gate 2) (both centered at a delay of 307 μs) data are used for analysis. In the case of isolated munitions in the far field (i.e. farther from the sensors than their characteristic dimension), UX-Analyze and the MTADS DAS employ resident physics-based models to determine anomaly position, size, shape, and depth and to provide estimations of anomaly orientation. An example of a working screen from UX-Analyze is shown in Figure 2-9. A spreadsheet (Excel 2003, Microsoft, Inc.) containing details of the anomaly location and fit parameters are provided along with the locations of anomalies above background which are identified by the operator but for which the dipole model do not give a reasonable fit. The located demedianed EM data are also provided for archival purposes.

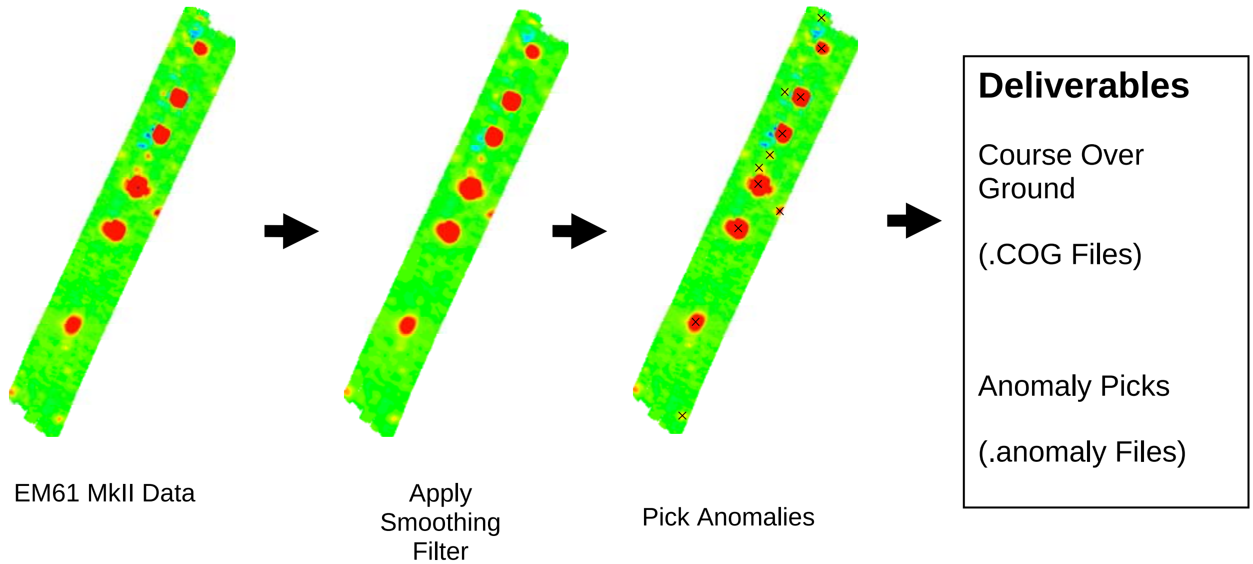

Figure 2-8 – Automatic anomaly detection scheme for the EM61 MkII Array. Example data is from the calibration lane at Former Camp Sibert Site 18. EM data is shown on a ±30 mV vertical scale.

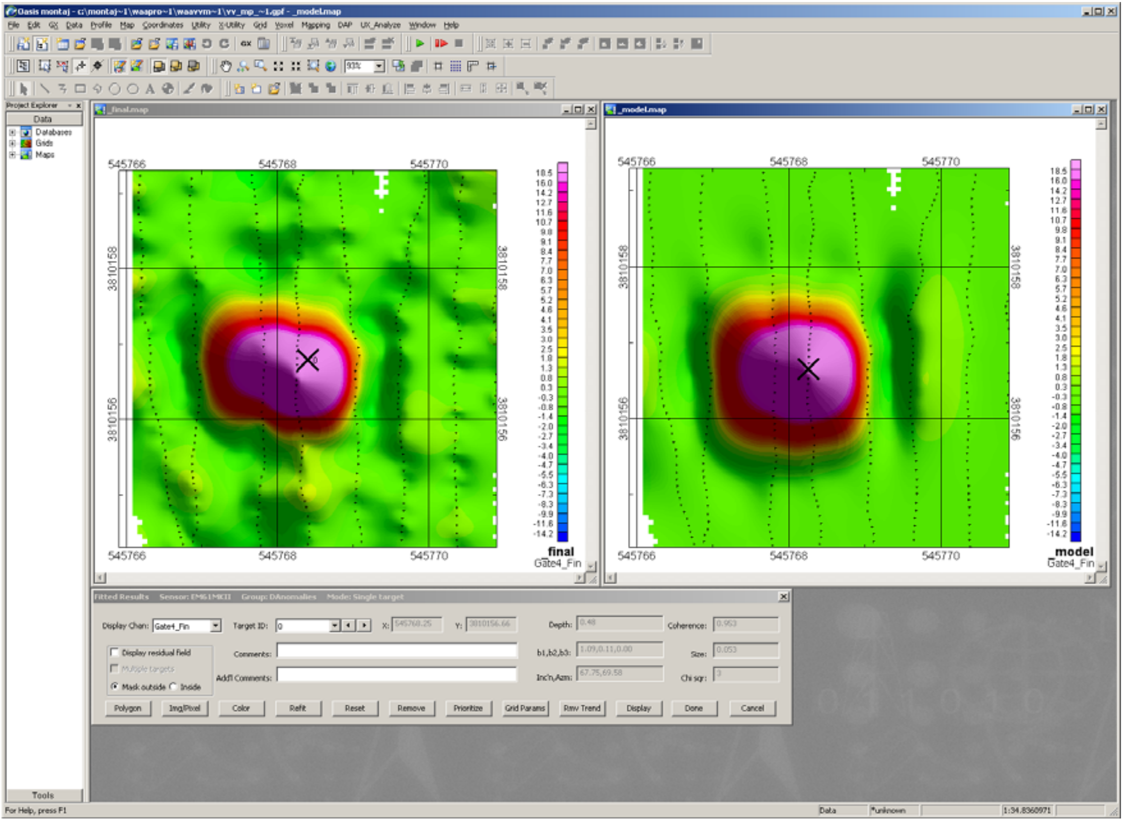

Figure 2-9 – Screenshot of the UX-Analyze working screen

2.1.4.2 Man-portable Data Analysis Methodology

Each data set is collected using a custom software package developed at NRL. The collected raw data are preprocessed on site for quality assurance purposes using standard MTADS procedures and checks. The data set is comprised of four files, each containing a single data source, each with a unique data rate. The data are merged and imported into a single Oasis montaj (v6.4, Geosoft, Inc.) database using custom scripts developed from the original MTADS DAS routines. An example of a working screen from Oasis montaj is shown in Figure 2-10. As part of the import process any data corresponding to a sensor outage, a GPS outage, or a COG stop / reverse, are defaulted or marked to not be further processed. Defaulted data are not deleted and can be recovered at a later time if so desired. Any long wavelength features such as sensor drift are filtered from the data (demedianed).

There is no cross-track information from which to generate a two-dimensional representation, so anomaly selection is done by looking for anomaly peaks along a downtrack profile. The EM61 MkII provides data for four time gates, the choice of which time gate to use for anomaly detection can be site-specific. As discussed in the previous section, the first few data sets collected on site are examined and an appropriate time gate is chosen for anomaly selection. The appropriateness of the choice is monitored throughout the demonstration. A built-in feature of Oasis montaj is then used to extract peaks above an empirically-determined threshold from the data. The detected

anomaly locations along with the signal magnitude at the peak of the anomaly are provided to the ESTCP Program Office. The down-sampled transect COG (~10 m spacing) are also provided.

For total coverage (100%) surveys areas, the located demedianed sensor data are imported into the UX-Analyze subsystem of Oasis montaj for individual anomaly selection and analysis. Based on experience, the combination of lower coil time gate 3 and the upper coil time gate (both centered at a delay of 660 μs) data are for the analysis. All anomalies with a peak intensity of greater than the anomaly detection threshold in the appropriate time gate are then analyzed. A spreadsheet (Excel 2003, Microsoft, Inc.) containing details of the anomaly location and fit parameters is provided along with the locations of anomalies above background which are identified by the operator but for which the dipole model do not give a reasonable fit. The located demedianed sensor data are also provided for archival purposes.

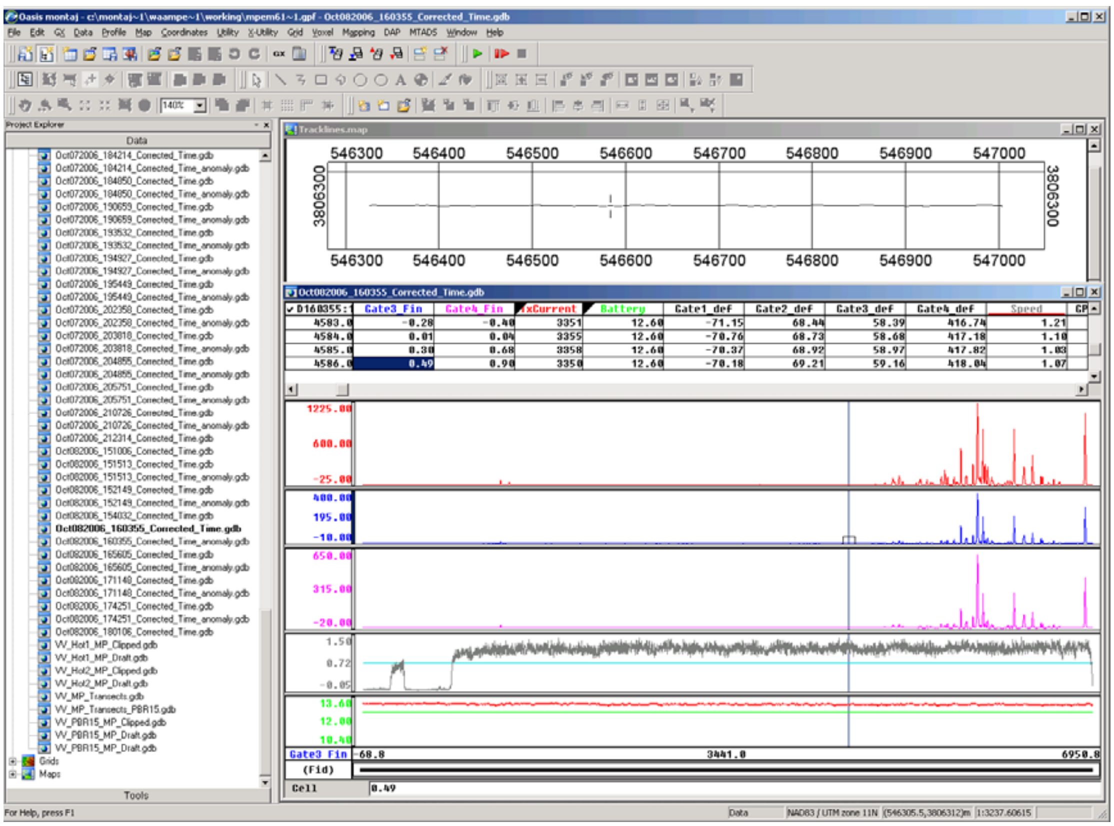

Figure 2-10 – Working screen in Oasis montaj™ of data preprocessing work flow

2.2 Previous Testing of the Technology

The Chemistry Division of the Naval Research Laboratory has participated in several programs funded by SERDP and ESTCP whose goal has been to enhance both the detection and the discrimination abilities of MTADS for both the magnetometer and EM-61 array configurations. The process was based on making use of both the location information inherent in an item's magnetometry response and the shape and size

information inherent in the response to the time-domain electromagnetic induction (EMI) sensors that are part of the baseline MTADS in either a cooperative or joint inversion. As part of ESTCP Project 199812, a demonstration was conducted on a live-fire range, the 'L' Range at the Army Research Laboratory's Blossom Point Facility [11]. In 2001, a second demonstration was conducted at the Impact Area of the Badlands Bombing Range, SD [12] as part of ESTCP Project 4003. The EM61 is a time-domain instrument with either a single gate to sample the amplitude of the decaying signal (MkI) or four gates relatively early in time (MkII). The first generation of the MTADS EM61 MkII array was demonstrated in 2001 [12] at the Badlands Bombing Range, SD with little demonstrable gain over the single decay of the MkI array. A second generation of the MkII array with updated electronics was constructed in 2003 as part of ESTCP Project 200413. The upgraded MTADS EM61 MkII array was demonstrated at both of the Standardized UXO Technology Demonstration Sites located at the Aberdeen and Yuma Test Centers in 2003 and 2004 [13]. Appendix A summarizes the Open Field scenario results of the APG demonstration. The response stage results for the EM61 MkII Array from the APG Open Field Scenario are shown in Figure 2-11 and Figure 2-12. The response stage results shown in Figure 2-11 are analyzed by excluding first items that were not covered by the survey or are within 2-m of another item then retaining those exclusions and further excluding items deeper than 11x their diameter.

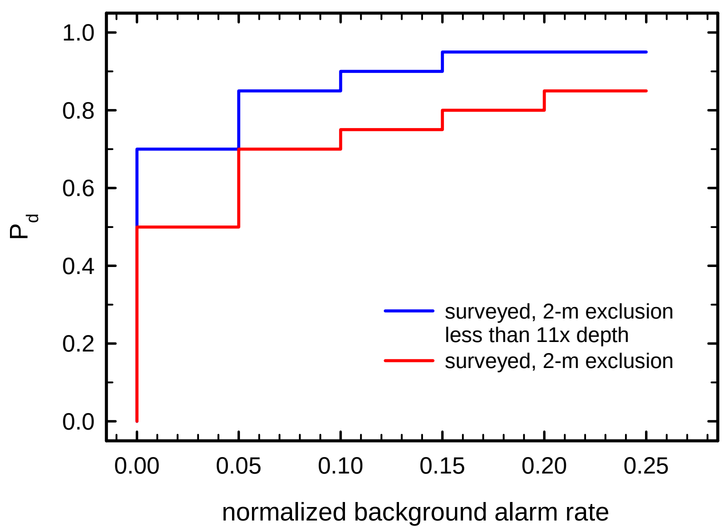

Figure 2-11 – MTADS EM61 MkII detection performance at the APG Open Field Scenario. The red line is derived considering only targets that were covered in the survey and are not within 2 m of another target. The blue line retains those criteria and also excludes targets deeper than 11x their diameter.

The response stage results are also broken out by munitions type in Figure 2-12. The depth of 100% detection is denoted by the blue bar and the depth of maximum detection is shown as the horizontal line. For some of the items, the 105-mm HEAT for example, these two depths are the same. For many of the items, the maximum depth of detection is below the depth of 100% detection.

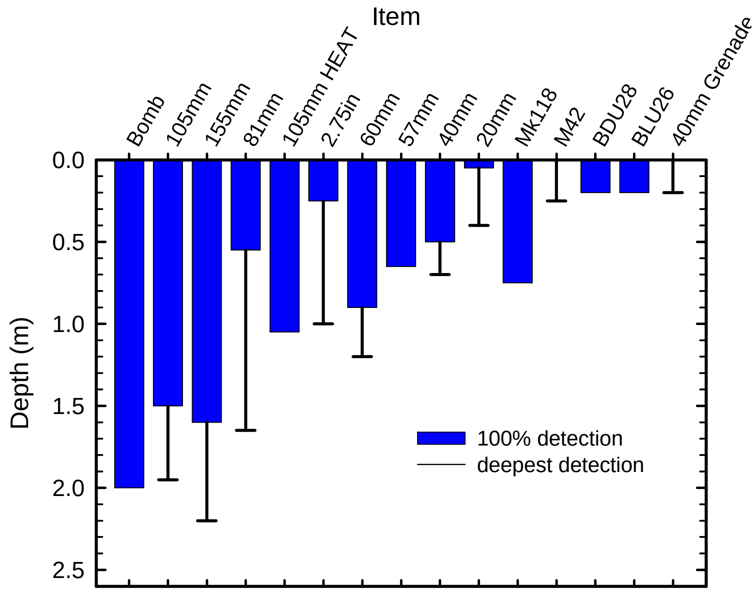

Figure 2-12 – MTADS EM61 MkII response stage results for the APG Open Field scenario broken out by munitions type

Reference 13 compares the detection-only performance of the MTADS magnetometer, the second-generation MTADS EM61 MkII, and the GEMTADS arrays to other demonstrators at both of the Standardized UXO Technology Demonstration Sites. All three sensor arrays were also demonstrated in the Spring of 2007 as part of the ESTCP UXO Discrimination Study at the Former Camp Sibert [14]. Data processing and the development of performance results for the various discrimination methodologies of the UXO Discrimination Study are currently ongoing.

The man-portable EM61 MkII system was successfully demonstrated for WAA and total-coverage surveys at the Victorville WAA demonstration site in the Fall of 2006 [9].

2.3 Advantages and Limitations of the Technology

On large open ranges the vehicular MTADS provides an efficient survey technology. Surveys with the magnetometer array often exceed production rates of 20 acres per day. UXO items with gauges larger than 20mm are typically detected to their likely burial depths. To reliably detect the smaller gauge munitions in this spectrum, the MTADS EM61 MkII array should be used rather than the magnetometer array. This process has to date involved a human operator manually selected the data corresponding to individual anomalies. Each data segment is then processed by a physics-based algorithm incorporated into the MTADS Data Analysis System (DAS) software or the equivalent UX-Analyze.

While this methodology has proven highly successful in the past, it is not fast enough to support the rapid data requirements for the transect surveys to be conducted as part of the ESTCP WAA Pilot Project. A faster, more automated method has been developed and

was demonstrated at the Pueblo Precision Bombing Range (PBR) #2 WAA site in the Fall of 2005 [7] and at the Victorville Precision Bombing Ranges Y and 15 WAA site in the Spring of 2006 [8]. The man-portable adjunct has been successful demonstrated with EM [9] and magnetometer [6] sensors. The location and amplitude of detected anomalies with amplitude above an empirically-determined threshold were reported to the ESTCP Program Office, PNNL, and SNL along with the survey COG for reference in near real time. This rapid feedback of information allowed for the interactive planning and execution of additional transects and total-coverage surveys for validation purposes while the demonstration was ongoing and the field team was still deployed.

The presence of certain terrain features such as deep ravines without good crossing points, thick clusters of trees, and other non-navigable features such as steep hill faces can limit the areas that can be surveyed. The presence of long barbed-wire fences without gates and deep ravines, steep hill and plateau faces without good access points can also slow survey operations by reducing survey line length and increasing travel time to traverse these obstacles. The southern portion of the site, which was used for primarily for mortars is heavily treed and valleyed. The MP EM system with its enhanced maneuverability was the primary survey instrument in this area. In part, the enhanced maneuverability of the MP EM system came from the use of a sub-meter level GPS receiver to operate under the tree canopy.

3. Demonstration Design

3.1 Performance Objectives

Performance objectives for the demonstration are given in Table 3-1 and Table 3-2 to provide a basis for evaluating the performance and costs of the technology to be demonstrated. Table 3-1 covers the primary performance objectives of this demonstration relating to the detection of target areas and non-target areas within the overall survey area. Table 3-2 contains secondary demonstration objectives/metrics relating to the extraction of additional information about the detected target areas and the anomalies within those areas. These objectives are for the technology being demonstrated only. Overall project objectives will be given in the overall demonstration plan generated by ESTCP. The final column, 'Actual Performance Objective Met?' will be added in future reports.

3.2 Testing and Evaluation Plan

3.2.1 Demonstration Set-Up and Start-Up

The initial Conceptual Site Model (CSM) for the Former Camp Beale FUDS prepared in conjunction with the 2004 Site Investigation [3] provides a great deal of information about the FUDS site. The following information was extracted from the draft WAA Demonstration Plan for Former Camp Beale [15]. The overall FUDS consists of 87,672 acres approximately 20 miles east of Marysville, California, in both Yuba and Nevada counties. Beale Air Force Base (AFB) currently occupies approximately 23,104 acres.

Former Camp Beale encompasses land in numerous sections of Townships 14 and 15 North and Ranges 5 and 6 East.

In 1940, the Camp Beale area consisted of grassland and rolling hills and the abandoned mining town of Spenceville. Marysville City officials encouraged the Department of War to establish a military facility in the area. The U.S. government purchased 87,000 acres in 1942 for a training post for the 13th Armored Division. Camp Beale also held training facilities for the 81st and 96th

Table 3-1 – Primary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method
Primary Metrics (Relating to Detection of Target Areas and Target-free Areas)			
Qualitative	*Reliability and Robustness*	*General Observations*	*Operator feedback and recording of system downtime (length and cause)*
	Terrain / Vegetation Restrictions	*General Observations*	*Correlation of areas not surveyed to available data (topographical maps, etc.)*
Quantitative	*Survey Rate*	*Towed: 16 lane km / day* *MP: 10 lane km / day*	*Calculated from survey results*
	Data throughput	*All data from day x processed for anomalies and submitted by end of day x+1*	*Analysis of records kept / log files generated while in the field*
	Percentage of Assigned Coverage Completed	*>95% as allowed by topography*	*Calculated from survey results*
	Transect Location	*95% within 10 meters of requested transects*	*Calculated from survey results*

Table 3-2 – Secondary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method
Secondary Metrics (Relating to Characterization of Target Areas)			
Qualitative	*Ability of Analyst to Visualize Targets from Survey Data*	*All targets in survey area identified*	*Data Analyst feedback and comparison to total-coverage data / other demonstrators results*
Quantitative	*Location of Inverted Targets*	*Horizontal: < ± 0.15 m Vertical: < 30% for depths ≥ 30 cm, < ± 0.15 m depths < 30 cm*	*Validation Sampling (100% survey) and/or Remediation Sampling (digging)*
	Signal to Noise Ratio (SNR) for Calibration Targets	*+/- 10% of expected from Standardized UXO Technology Demonstration Site Performance*	*Comparison of Calibration Target results to documented Standardized UXO Technology Demonstration Site performance*
	Data Density	*> 20 pts / m^2*	*Calculated from survey results*

Infantry Division, a 1,000-bed hospital, and a prisoner of war camp. As a complete training environment, Camp Beale had tank maneuvers, mortar and rifle ranges, bombardier-navigator training, and chemical warfare classes. During WWII, Camp Beale had 60,000 personnel. In 1948, Camp Beale became Beale Air Force Base (AFB), its mission to train bombardier-navigators in radar techniques. The Base established six bombing ranges of 1,200 acres each. The U.S. Navy also used Beale AFB for training. From 1951 on, Beale trained navigation engineers and ran an Air Base Defense School. These additional activities led to the rehabilitation of existing Base facilities and construction of rifle, mortar, demolition, and machine gun ranges. In 1958 the first runway was operational. One year later, the installation ceased being used as a bombing range and the U.S. Government declared portions of Camp Beale/Beale AFB as excess, eventually transferring out 60,805 acres. On December 21, 1959, 40,592 acres on the eastern side of the Base were sold at auction. An additional 11,213 acres was transferred to the State of California between 1962 and 1964, and now comprise the Spenceville Wildlife and Recreation Area. In 1964-1965, another 9,000 acres were sold at auction.

The 2006 WAA demonstration area is limited to approximately 18,000 of these acres. An area was chosen that overlaps with a number of historic ranges, has suitable topography to give further insight into the applicability of the WAA techniques, and faces the highest development pressure of any part of the FUDS project. The WAA demonstration area is shown in Figure 3-1 plotted over an aerial photograph of the FUDS in pink. Typically, the approximate coordinates for the survey area would be included as a Table in this document. However, with 1,124 vertices, the boundary for this site will only be available electronically. As can be seen from Figure 3-1, the WAA site encompasses a large, rolling area in the northwest that is relatively free of tall vegetation and two valleys in the Spenceville Wildlife and Recreation Area (shown in blue in Figure 3-1) that are bounded

by trees and hillier terrain. The WAA site contains a number of the targets used during the period 1948 through 1959. Information on these ranges is available in the CSM [3]. At present, the WAA site is used almost exclusively for recreation and cattle grazing. A large portion is located in the Spenceville Wildlife and Recreation Area. The remainder is in private hands. A portion of the open area in the NW part of the site has been assembled for development but is currently being used for cattle grazing.

The MTADS systems were mobilized to the Former Camp Beale site in a U.S. Navy-owned 53-ft trailer. The tow vehicle, the EM trailer, MP EM system, notebook computers for the analysis team, GPS equipment, batteries and chargers, office equipment, radios and chargers, tools, equipment spares, and maintenance items, and sensors were transported in the trailer. A government contract transportation firm, Harris Transportation was contracted to transport the trailer to the demonstration site.

The State of California Department of Fish and Game graciously made their fenced-in maintenance area within the Spenceville Wildlife and Recreation Area available to this demonstration as a base camp area. Due to the remoteness of the survey site, no essential support services are available on-site. Accordingly, Nova Research made provisions to acquire all of the requisite supplies, materials, and facilities from local rental firms. An office trailer was used for data processing and analysis, as a communications center, for battery storage and charging stations, as an electronics repair station, and as storage for spares and supplies. This trailer was provided with AC power, heating, and cooling. A second 8’ x 40’ trailer, which could be fully opened from either end (for drive-through access), was used to garage and for secure storage of the MTADS vehicle and sensor platform. Additional 8’ x 40’ storage containers were used to establish two auxiliary base camps to store the towed array system when daily travel distances become too long for the vehicle due to the size of the site. One (middle) was situated on private property off of Smartsville Road for access to the Projectile and Bomb Areas. The third (north) was located within the Spenceville Wildlife and Recreation Area north of Hammonton – Smartsville Road.

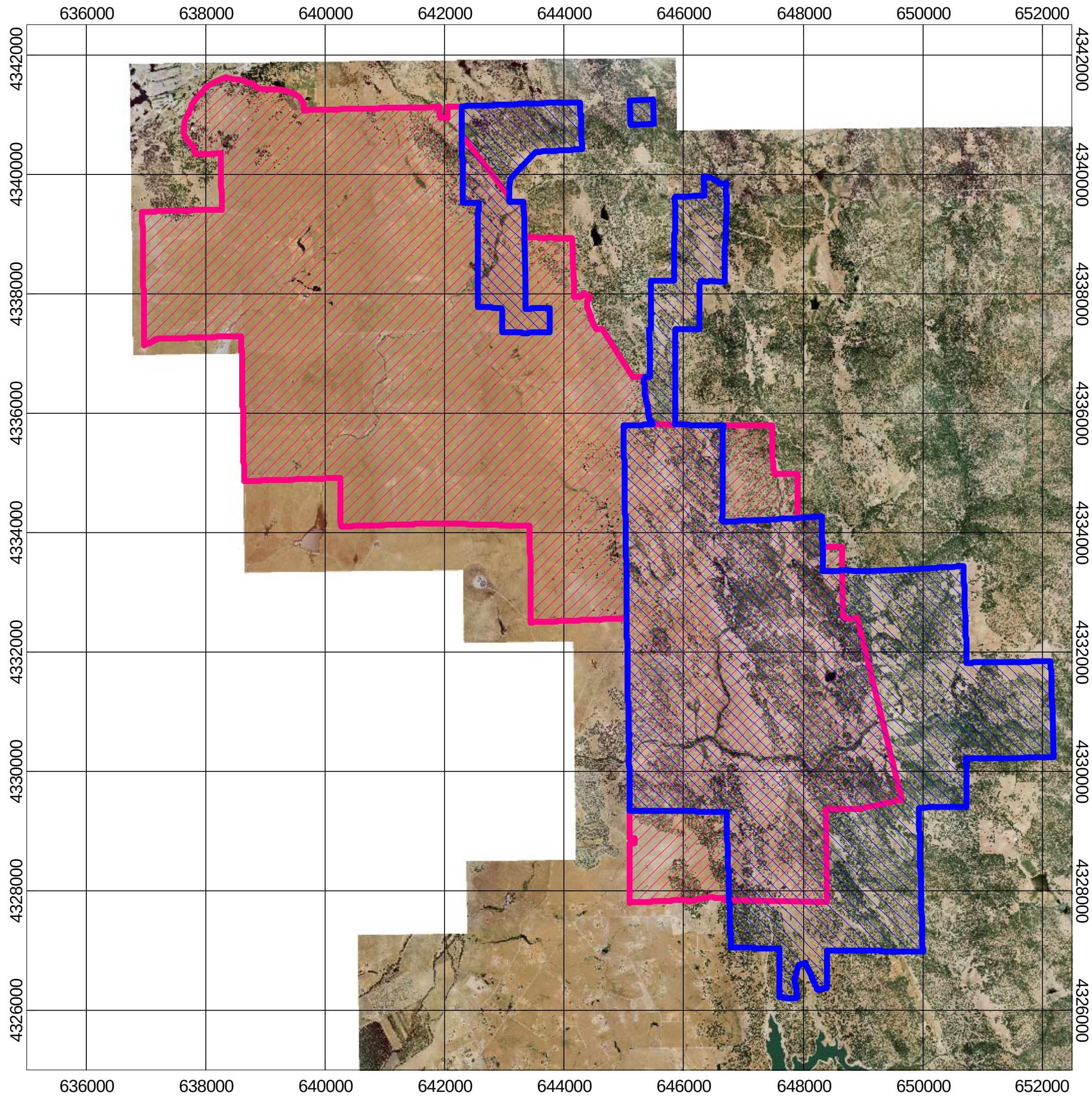

Figure 3-1 – Wide Area Assessment Demonstration site overlaid (in pink) on an aerial photograph of the Former Camp Beale FUDS. The boundaries of the Spenceville Wildlife and Recreation Area are shown in blue.

Power to the main base camp trailers was provided by a diesel field generator (35 kW range) that was used to recharge the vehicle, radios, and GPS batteries overnight. A smaller 4 kW generator was used at the auxiliary base camps for power. Communications among on-site personnel was provided by hand-held VHF radios. At least one radio was provided to all field teams. The availability of cellular phone communications on site is non-continuous but was available in various locations within the site. The locations of good cellular service were shared among the field team for use as available. Fuel storage was provided for the generator and portable toilets were provided at the main base camp area to support all field and office crews with weekly

servicing. Figure 3-2 shows the arrangement of this logistics support at a recent survey. One portable toilet was later relocated to the northern auxiliary base camp for convenience.

Figure 3-2 – Photo of a recent MTADS field base camp showing the relative locations of the logistics support trailers, etc.

Upon arrival, the team personnel unpacked the 53’ trailer and established the main base camp. URS Corporation, of Seattle, WA previously established a network of geodetic survey points within the demonstration area as part of their high-airborne data collection. The coordinates of the control points are given in Table 3-3 (horizontal datum: NAD83 (National Spatial Reference System); vertical datum: NAVD88; geoid model: Geoid 03). The RTK GPS base station receiver and radio link was established on C12, one of the available established control points. C12 was the control point used for a majority of the demonstration. The validity of the control point locations was verified using a man-portable RTK GPS rover receiver to occupy several of the other established control points using the GPS base station established on C12 as a reference. It was discovered during the demonstration that not all of URS’s established control points were still emplaced. C16, C2, C5, C6, and C8 were either located or reestablished using C12 as a reference. Control point locations and validity were further verified throughout the survey campaign as required and/or directed by the Quality Assurance Officer (QAO). The EM trailer was connected to the tow vehicle and the system powered up. The connectivity of the EM sensors to the DAQ computer and the establishment of normal SNR performance were verified along with the operational state of the vehicle RTK system. A period (5-10 minutes) of quiet, static data was collected and submitted to the Data Analyst for validation. This test was repeated throughout the survey campaign as directed by the QAO. The MP EM system setup and initial testing procedures followed a similar pattern to that of the towed array system.

A lane of emplaced calibrations items was to be installed in the general vicinity of the main base camp, however the background levels recorded by the MkII sensors were sufficiently high to make the main base camp site unworkable. The items were emplaced near the middle connex and used for daily calibration when the vehicle was based out of the middle connex. The schedule of calibration items for ground-based EM systems as emplaced is given in Table 3-4. The objects were buried in two parallel lines with 10 – 20-m spacing between items. The locations of each item (nose and tail) were recorded

using cm-level GPS. A single-pass survey of the emplaced calibration lane area was conducted to record the signatures of the emplaced items. The data was submitted to the Data Analyst for analysis of signal amplitude, SNR, and location accuracy. When all system checks were completed to the satisfaction of the QAO, the main survey commenced.

Table 3-3 – Survey Control Points Installed for the Former Camp Beale WAA Demonstration Site

Point Name	Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	Elevation (m)
	NAD83/NSRS			UTM Zone 10N, NAD 83		NAVD88
C001	39º 12’ 01.15299” N	121º 20’ 55.70019” W	135.713	4,340,305.427	642,579.791	163.562
C002	39º 11’ 06.28622” N	121º 20’ 53.38796” W	131.327	4,338,614.954	642,666.080	159.257
C003	39º 11’ 27.85751” N	121º 21’ 00.37808” W	155.127	4,339,276.919	642,486.266	183.037
C004	39º 11’ 09.68429” N	121º 22’ 53.47148” W	84.628	4,338,667.747	639,783.110	112.773
C005	39º 10’ 23.51730” N	121º 19’ 34.45534” W	204.346	4,337,331.169	644,584.214	232.195
C006*	39º 09’ 39.79243” N	121º 19’ 23.53646” W	152.317	4,335,988.021	644,871.153	180.222
C007	39º 09’ 18.87655” N	121º 20’ 42.97233” W	159.408	4,335,308.197	642,976.398	187.498
C008	39º 11’ 41.26559” N	121º 20’ 54.05094” W	158.170	4,339,693.040	642,630.525	186.046
C009	39º 10’ 21.48044” N	121º 24’ 52.20405” W	68.860	4,337,131.349	636,960.456	97.270
C10	39º 10’ 43.13112” N	121º 23’ 52.26739” W	65.029	4,337,824.090	638,386.939	93.315
C11**	39º 06’ 47.49614” N	121º 18’ 03.74327” W	95.331	4,330,711.969	646,885.694	123.402
C12	39º 07’ 26.95524” N	121º 18’ 05.83418” W	113.925	4,331,927.503	646,812.719	141.927
C13	39º 07’ 46.20589” N	121º 17’ 13.81398” W	148.438	4,332,544.449	648,050.700	176.306
C14***	39º 08’ 09.07400” N	121º 17’ 23.57661” W	136.671	4,333,245.026	647,803.000	164.515
C15	39º 08’ 39.59524” N	121º 18’ 07.73617” W	191.755	4,334,166.052	646,725.151	219.626
C16	39º 07’ 01.94818” N	121º 18’ 28.90014” W	85.013	4,331,146.224	646,273.197	113.103
C17	39º 06’ 39.62811” N	121º 16’ 34.75768” W	100.457	4,330,509.689	649,027.475	128.376
C18	39º 06’ 15.40276” N	121º 18’ 11.70543” W	98.352	4,329,718.997	646,712.954	126.495

* Given coordinates represent the inside corner of SE Leg of target
** Static Airbase during data acquisition
*** Given coordinates represent the inside corner of NE Leg of target

Table 3-4 – Schedule of Ground-based System WAA Calibration Items, EM Configuration

Item	Depth	Azimuthal Orientation of Nose or Thread Section
16-lb shotput	2 @ 25 cm	N/A N/A
37mm simulator	10 cm 32 cm	Down-Track Vertical
60mm mortar	10 cm 28 cm	Down-Track Cross-Track
81mm mortar	25 cm 40 cm	Cross-Track Down-Track
105mm projectile	40 cm 60 cm	Down-Track Cross-Track
155mm projectile	65 cm 100 cm	Down-Track Down-Track

Surveys of the calibration items were conducted at the beginning and end of each work day and as directed by the QAO. For survey days when the vehicle was not based out of the middle connex, ad hoc calibration lanes were established using additional steel shotputs. The MP EM system was generally mobilized out of the main base camp. A calibration lane comprised of a 4”- and a 3”-diameter Al sphere was established at the base camp for the MP EM system to use the calibration lane for daily systems checks. When the MP EM system was not staged out of the main base camp, ad hoc calibration lanes were established using additional steel shotputs. See Section 3.2.7 for a more detailed discussion.

The Site Safety Officer conducted a ‘tail-gate’ safety meeting each day that personnel are on site. The topic(s) for each day’s meeting were at the discretion of the Site Safety Officer. Roll was taken in the form of a sign-in sheet. Refer to Appendix D: MTADS Safety, Health, and Emergency Response Plan of the Demonstration Plan [16] for all other site safety related information.

Preventative maintenance inspections were conducted at least once a day by all team members, focusing particularly on the tow vehicle, sensor trailer, and MP EM platform. Any deficiencies were addressed according to the severity of the deficiency. Parts, tools, and materials for many maintenance scenarios are available in the system spares inventory which was available on site. Any break-downs / failures resulting in delays of any significant period of time were reported to the WAA Pilot Project Manager in a timely fashion.

3.2.2 Period of Operation

The schedule of the major events in the Demonstration is given in tabular form in Table 3-5. The vehicular survey was completed on June 22, 2007. The man-portable survey was extended two weeks, ending on July 6, 2007.

3.2.3 Scope of Demonstration

Data collection was conducted at the Former Camp Beale WAA Pilot Project Demonstration Site, 20 miles east of the City of Marysville, CA at the request of the ESTCP Program Office. A series of EM61 MkII transect surveys were conducted over the site according to the transect plan provided by PNNL in cooperation with the ESTCP Program Office and SNL using a combination of towed-array and man-portable platforms. The transect plan generated by PNNL [17] segments the site into three different MRAs based on historical data from the ASR used in conjunction with the recently obtained LiDAR and ortho-photography data for the Former Camp Beale WAA demonstration site. These three areas are shown in Figure 3-3, Figure 1 from Reference 17. The Mortar Area (green) is based on target areas for 81mm mortars. The Projectile Area (yellow) is based on target areas created by 105mm projectiles and the Bomb Area (red) contains target areas generally created by bombing targets.

Table 3-6 – Table 3-9, Tables 1 – 4 from Reference 17, summarize the sampling design parameters for the three areas. The transect plans for the 81mm mortar area and the 105mm projectile area are based on a 1-m transect width, the transect width of the MP EM system. Due to the terrain and foliage coverage of the 81-mm mortar area, the man-portable system was required for all but the most open portions of the area.

Table 3-5 – Former Camp Beale WAA Demonstration Final Schedule

Date	Planned Action
Week of May 7th	Packed 53' trailer at Blossom Point.
Tue, May 15th	Trailer left Blossom Point for Marysville, CA.
Thu, May 17th	CDFG representative accepted partial delivery on base camp logistics.
Sun, May 20th	Vehicular team personnel arrived in Marysville, CA. 53' trailer arrived at site in Marysville, CA. Received 53' trailer.
Mon, May 21st	Unpacked 53' trailer. Assembled MTADS system. Established Base Camp.
Tue, May 22nd	Began vehicular survey.
Sun, May 27th	Man-portable team personnel arrived in Marysville, CA.
Mon, May 28th	Began man-portable survey.
Fri, June 22nd	Completed vehicular survey.
Mon, June 25th	Packed 53' trailer. Demobilization of base camp commenced.
Tue, June 26th	53' trailer departed for Blossom Point, MD.
Wed, June 27th	Two team members departed Marysville, CA.
Mon, July 2nd	53' trailer arrived at Blossom Point, MD.
Wed, July 4th	Completed man-portable transect survey.
Thu, July 5th	Began man-portable total coverage survey.
Fri, July 6th	Completed man-portable total coverage survey.
Sat, July 7th	Shipped man-portable equipment to Blossom Point. Remaining personnel departed Marysville, CA.
Week of Sep 10th	Submited Draft Data Report to ESTCP.

Sub-meter GPS was required for operations in a majority of the area as well. For the 105mm projectile area, the two systems were used to achieve the best efficiency and coverage possible. The 100-lbs bomb area is mostly open grassland and was mainly surveyed with the towed array system. The MP EM system was deployed to two small and/or remote areas that the vehicle could not reach. The transect plan, shown in Figure 3-4 (Figure 5 from Reference 17), is laid out on an area-by-area basis to best match the local terrain to facilitate data collection.

The detected anomaly locations (easting, northing) along with the peak signal magnitude (mV, S1) were extracted for each anomaly above an empirically determined threshold for

all transect data. The first sets of data were used to choose an appropriate time gate and detection threshold for each system.

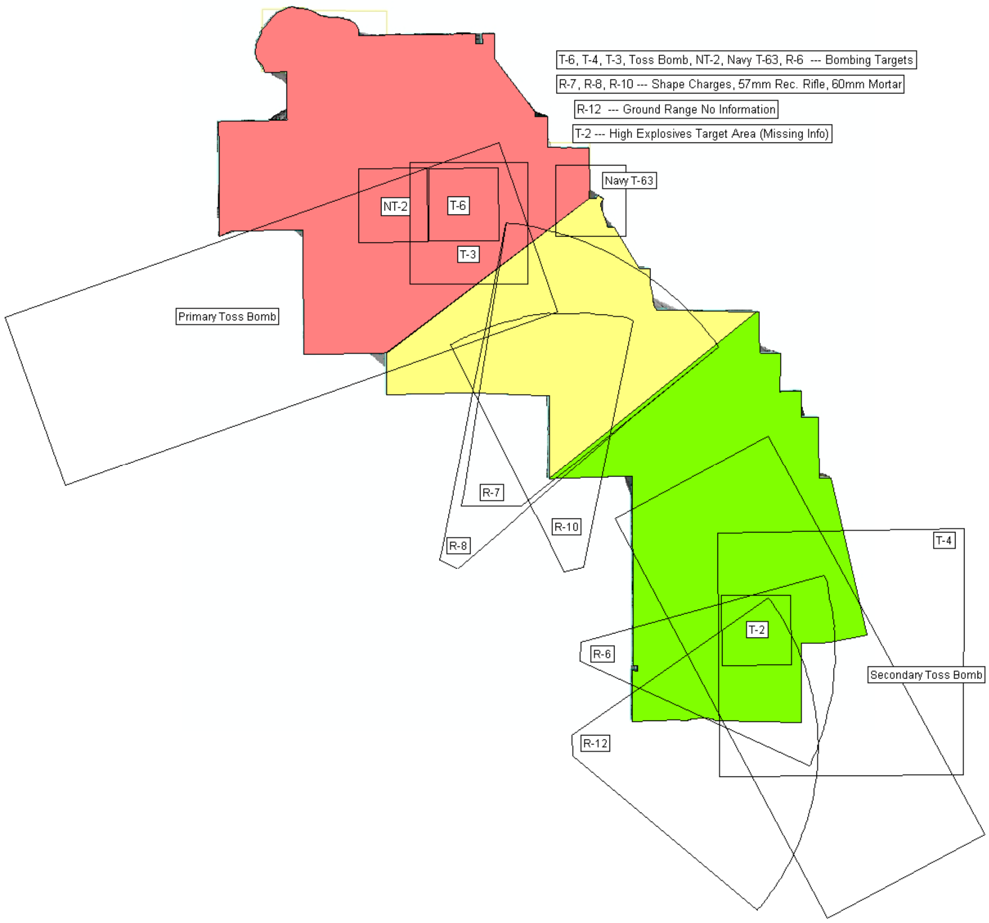

Figure 3-3 – Camp Beale WAA study area segmented into three separate transect designs. The Mortar Area (green) is based on target areas for 81mm mortars. The Projectile Area (yellow) is based on target areas created by 105mm projectiles and the Bomb Area (red) contains target areas created by bombing targets.

After several days of data collection, the thresholds for the two systems were reviewed in cooperation with the Program Office and PNNL. As a result of the review, a new threshold was established for the MP EM system for improved cross-system comparison and to generate a single data set. See Section 3.2.4 for a detailed discussion. The down-sampled transect COG (6 – 10 m spacing) were also provided. Data collection begin with transects as best located outside the suspected target areas in the Mortar Area as possible to allow for the establishment of a non-target area baseline for the cut-off threshold based on the determined noise floor. Starting with twice the measured site-specific noise floor, the threshold was raised in increments of the noise floor until the Data Analyst was satisfied with the performance of the automated routines on the collected transect data and the calibration items. For the Former Camp Beale WAA Demonstration Site, a towed-array threshold of 40 mV, S1 was chosen. For the MP EM system, an initial

threshold of 7 mV was chosen, which was later revised to 15.5 mV, S1 to better correspond to results from the towed array. Past experience has shown that for the towed-array system, time gate 1 data and a threshold of 10 mV has provided acceptable results. For the man-portable EM system, time gate 1 data and a threshold of 4-6 mV was found to be acceptable at the Victorville WAA demonstration site [9].

Table 3-6 – Summary of coverage for the 81mm portion (Mortar Area) of the site

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a target area that has a specified size and shape
Type of Sampling Design	Transect
Selected sample area	81mm projectiles (green area)
Area of sample area	6,700 acres
Shape of target area of concern	Circular
Radius of target area of concern	400 feet
Transect pattern	Parallel
Transect width	1 meters
Computed spacing between Transect centers	450 feet
Probability of traversing the target area	100%
Total length of Transects	197 km

Table 3-7 – Summary of coverage for the 105 mm projectiles portion (Projectile Area) of the site

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a target area that has a specified size and shape
Type of Sampling Design	Transect
Selected sample area	105 mm projectile (yellow area)
Area of sample area	3985 acres
Shape of target area of concern	Circular
Radius of target area of concern	600 feet
Transect pattern	Parallel
Transect width	1 meters
Computed spacing between Transect centers	700 feet
Probability of traversing the target area	100%
Total length of Transects	75.5 km

This selection method retains the maximum sensitivity possible for the site without introducing additional extraneous anomalies. See Reference 10 for a more detailed discussion of the selection of the cut-off threshold value based on several previous sites.

For areas where 100% coverage surveys are conducted, the anomaly parameters (easting, northing, depth, size, etc.) from a standard MTADS DAS analysis, or equivalent, were reported as an anomaly report for all detected anomalies. See Appendix B, Section B.9 for an example of the anomaly report format.

The towed-array system operated for 5 weeks collecting transect data in the three survey areas based on the original transect plan and four additional requested transect sets.

Table 3-8 – Summary of coverage for the 100-lb bombs portion (Bomb Area) of the site

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a target area that has a specified size and shape
Type of Sampling Design	Transect
Selected sample area	100 lb bombs (red area)
Area of sample area	7,575 acres
Shape of target area of concern	Circular
Radius of target area of concern	700 feet
Transect pattern	Parallel
Transect width	2 meters
Computed spacing between Transect centers	880 feet
Probability of traversing the target area	100%
Total length of Transects	113.5 km

Table 3-9 – Summary of coverage for the entire Former Camp Beale WAA demonstration site

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a target area that has a specified size and shape
Type of Sampling Design	Transect
Selected sample area	All
Area of sample area	18,261
Shape of target area of concern	Circular
Radius of target area of concern	400,600, and 700 feet
Transect pattern	Parallel
Transect width	1 and 2 meters
Computed spacing between Transect centers	450, 700, and 880 feet
Probability of traversing the target area	100% for all three
Total length of Transects	386 km

The MP EM system operated for six weeks in the three areas but primarily in the Mortar Area based on the original transect plan and one additional requested set of transects. Two total coverage areas of 0.5 to 1.0 ha in area each were also surveyed using the MP EM system. Two hundred and twenty-five (225) lane-km were surveyed by the towed array system and 178 lane-km were surveyed by the man-portable system, totaling 403 lane-km. This corresponds to 110 acres for the towed array survey with a 2-m transect width and 45 acres) of man-portable survey with a 1-m transect width, or a coverage of 0.8% of the entire 18,000 acre site.

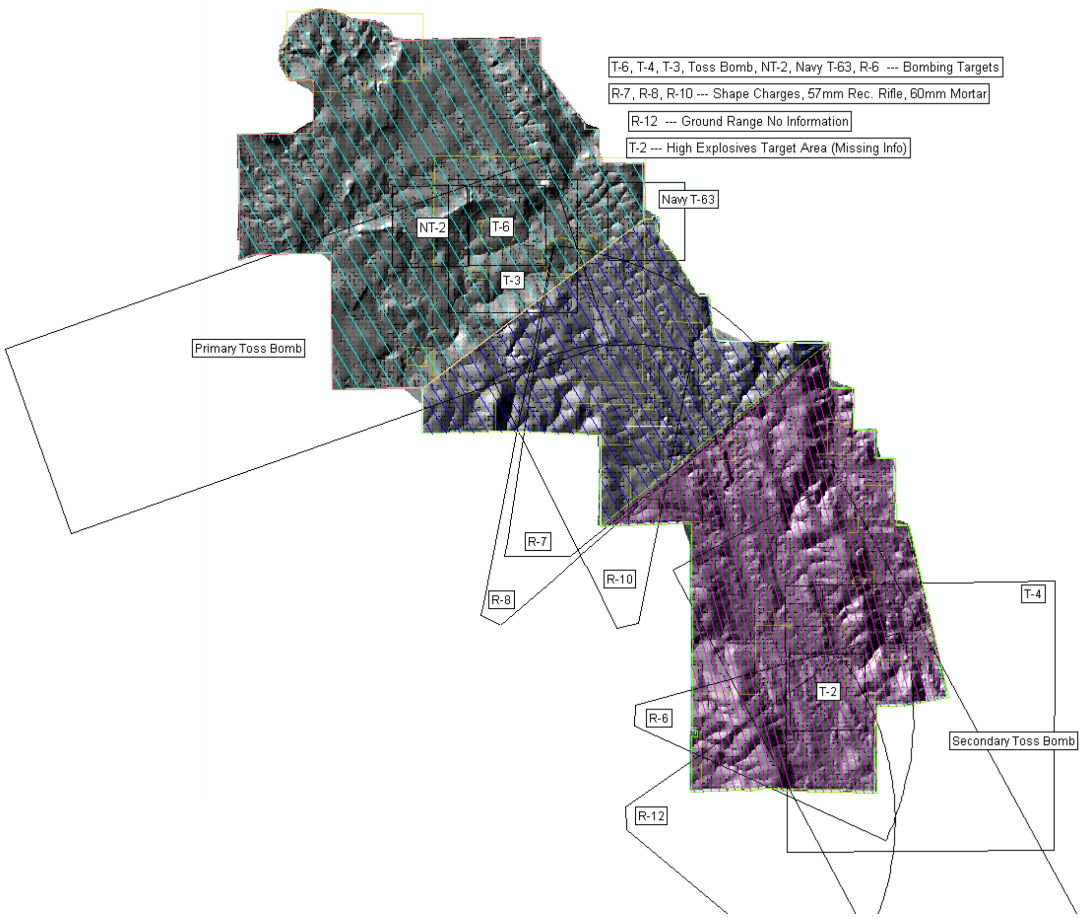

Figure 3-4 – The Beale WAA site divided into 3 areas with the transect design specific to each area depicted. The transects in the southern area follow the pattern of the valleys in the southern region and the transects in the two northern areas follow the pattern of the valleys on the northern part of the site

3.2.4 Operational Parameters for the Technology

The precision collection of high SNR data using the MTADS platform is a mature technology. The rapid and accurate extraction of anomaly location and a measure of anomaly amplitude from high-volume transect data collection is the novel component of this series of demonstrations. To accomplish this task an automated methodology of extracting the anomaly locations from the survey data was required. Such a methodology has been developed and is discussed in detail in Reference 10.

Briefly, an anomaly extraction threshold is determined based on the site-specific dynamic background floor. When the first survey results from a calibration strip (if available) and several early transect data sets at the site are available, these data are used to determine the dynamic noise level at the site from quiet portions of the data. Starting with an anomaly extraction threshold equal to the dynamic background level, the anomaly extraction threshold is increased in increments of dynamic background level (i.e. 2.5 nT/m for Pueblo PBR #2 magnetometer survey) and the site-specific anomaly extraction threshold is determined.

Diagnostics testing on the Blossom Point Test Field with the MTADS EM61 MkII array suggested that the anomaly extraction threshold could be as low as 10 mV, S1. Five of the first transect data sets from the Former Camp Beale site were analyzed in the described manner. The fall off behavior for the data sets is shown in Figure 3-5. Based on experience from determining the extraction thresholds from other demonstrations and the fall-off behavior, a peak extraction threshold of 40 mV, S1 was selected. While the validity of this decision was monitored throughout the demonstration, no changes were made to the anomaly extraction threshold for the vehicular system.

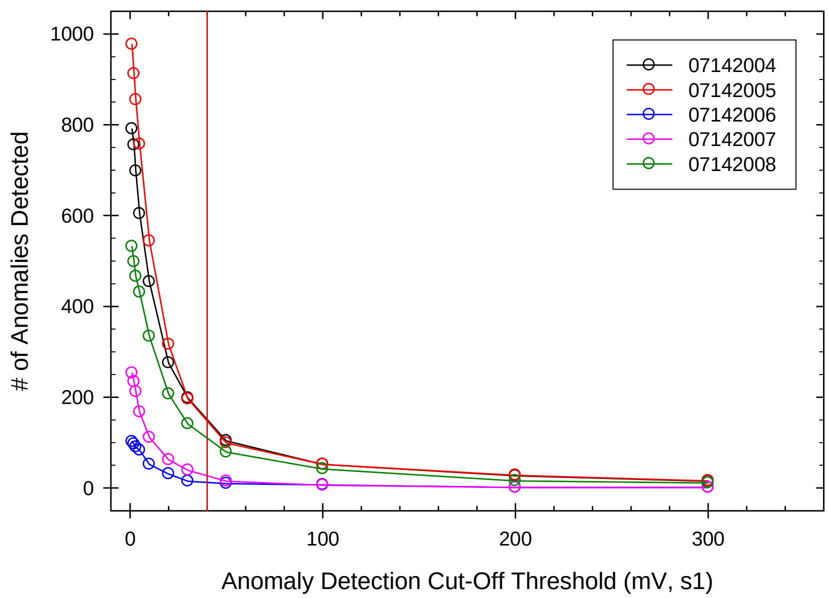

Figure 3-5 – Peak anomaly cut-off threshold analysis for the 07142 vehicular data sets from Former Camp Beale. The red line indicates the result for the final parameter value, 40 mV, s1.

The MP EM system has been previously demonstrated as part of the ESTCP WAA Pilot Project [9] at the Victorville WAA site. For the Victorville demonstration, the RMS variation in the sensor data from quiet portions of the data was evaluated and found to be 0.3 – 0.8 mV, S1 or roughly 5 times the static sensor noise levels. Using the same process outlined above for determining the anomaly extraction threshold, an anomaly extraction threshold value of 4 mV, S1 was found to be the best compromise between sensitivity and spurious anomaly detection and was used for this demonstration. The results for several early data sets from the Victorville MP EM demonstration are shown

in Figure 3-6. The chosen threshold is shown as a vertical red line. See Section 3.1.5 of Reference 9 for a comparison of the anomaly selection methods for both the magnetometer array and the MP EM system.

The same methodology was used for the MP EM system in this demonstration. Four of the first transect data sets from the Former Camp Beale site were analyzed in the described manner. The fall off behavior for the data sets is shown in Figure 3-7. Based on experience from determining the extraction thresholds from other demonstrations and the fall-off behavior of these data sets, a peak extraction threshold of 7 mV, S1 was selected. The validity of this decision was monitored throughout the demonstration, and on June 21, 2007 it was decided in cooperation with the Project Manager, PNNL, and SNL to adjust the threshold upwards to 15.5 mV, s1 to provide better correspondence with the vehicle system results. All data sets collected to date (through June 19) for both systems were evaluated in the course of the discussion. The results, shown in Figure 3-8, indicate that a man-portable threshold of 15.5 mV, s1 yields the same number of anomalies/km as the vehicular system with a threshold of 40 mV, s1 for the entire data collection. After this adjustment no further changes were made to the extraction threshold. Given the results shown in Figure 3-8, it is clear that the two distributions differ. The differences are likely due to a) system differences (time gates, spatial footprints, and transmit power levels) and b) the fact that there was little overlap between the survey areas of the two systems to maximize production efficiency.

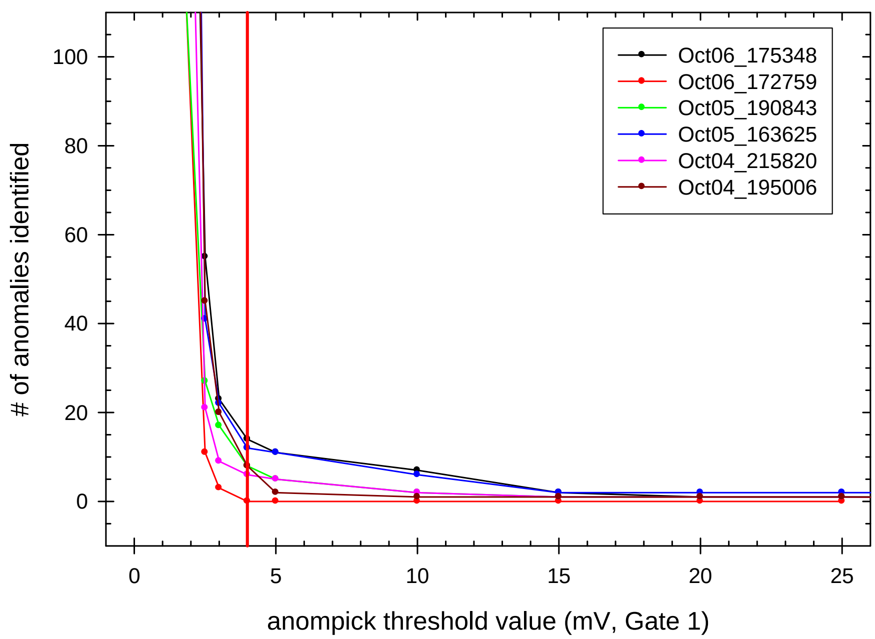

Figure 3-6 – Effect of increasing minimum peak height threshold value for early Victorville MP EM data set results. The red line indicates the result for the final parameter value.

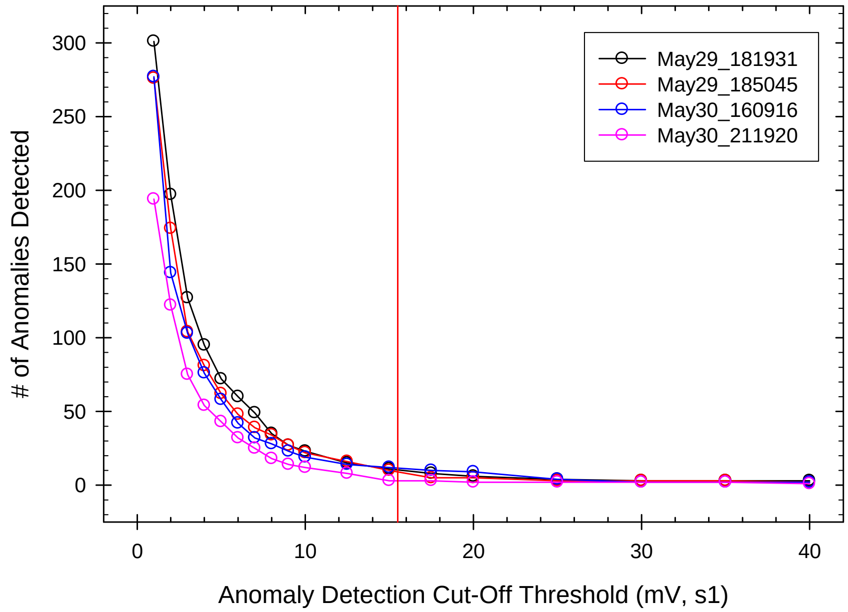

Figure 3-7 – Peak anomaly cut-off threshold analysis for Former Camp Beale MP EM data sets from May 29 and 30, 2007. The red line indicates the result for the final parameter value, 15.5 mV, s1.

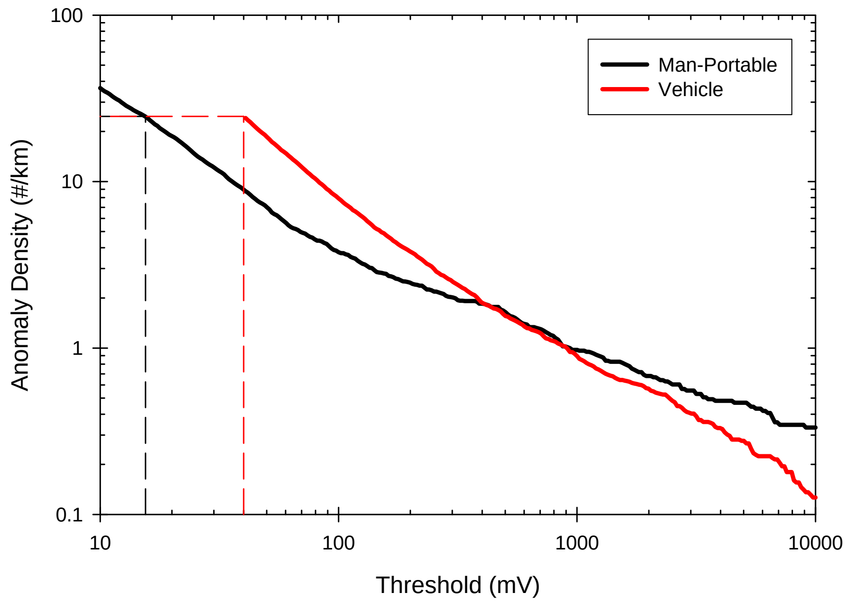

Figure 3-8 – Comparison of MP EM and vehicular anomaly extraction results. Anomaly density (anomalies/kilometer of transect) is plotted versus anomaly extraction threshold (mV, s1). The dashed lines indicate the final threshold values.

3.2.5 Transect Results

The major focus of the data collection effort for the demonstration was the collection of transect EM data following the original transect plan PNNL based on the archive data (CSM) and WAA Pilot Project goals as outlined in Section 3.2.3. The towed-array system covered 224.3 lane-km of the transect plans for the three areas. The man-portable system covered an additional 177.7 lane-km, mostly focused on the Mortar Area. The man-portable system did provide coverage of Bomb and Projectile Area transects that were not accessible to the towed-array system The navigation (track files) for the transect plan are provided on the attached DVD in both MTADS Pilot Guidance and Garmin formats. Five additional areas of interest were identified from the transect data by PNNL / SNL, labeled Bomb Area South, Bomb Area Central, Central, and Mortar Area, and Man Portable Additional (Mortar Area). Navigation files for the additional transect request are also included on the attached DVD. In these additional AOIs, a small number of additional transects, typically 4-5, oriented at 90 degrees to the original transect plan were designed by PNNL. The vehicular system surveyed 22.5 lane-km of the additional non-MP transects on June 21 and 22, 2007 prior to the end of vehicular operations on June 22, 2007. The man-portable team surveyed 12.5 lane-km of the additional man-portable transects July 3 and 4, 2007. The remaining lane-km were located in areas that were inaccessible.

The position (easting, northing) and signal strength (peak signal (s1, mV)) were extracted for each anomaly above an empirically threshold independently determined for each system. Figure 3-9 shows the results of all transect data collected in the course of this demonstration. The towed-array COGs are shown as magenta lines and each detected anomaly is shown as a green-filled circle. Man-portable transect COGs are shown as green lines and individual detected anomalies are shown as red-filled circles.

The total acreage covered by transect surveys was 155 acres, or approximately 0.8% of the total 18,000 acre site. Natural topology (ravines, dense boulder fields, etc.) made it difficult and impractical to complete each transect in a single survey. Therefore each transect was broken into one or more segments in the field. The flexibility of the MTADS Pilot Guidance software allows for this to be done easily and on the fly. The exact details of the area covered by each survey file are given in Excel spreadsheets on the attached DVD (Camp Beale Veh Transect Summary.xls and Camp Beale MP Transect Summary.xls) by system. An excerpt of the annotated listing for the towed array is given in Table 3-10. The demedianed EM61 MkII data, the anomaly list, and the COG files for each transect survey are also supplied on the attached DVD in the "Transect Surveys" subdirectory.

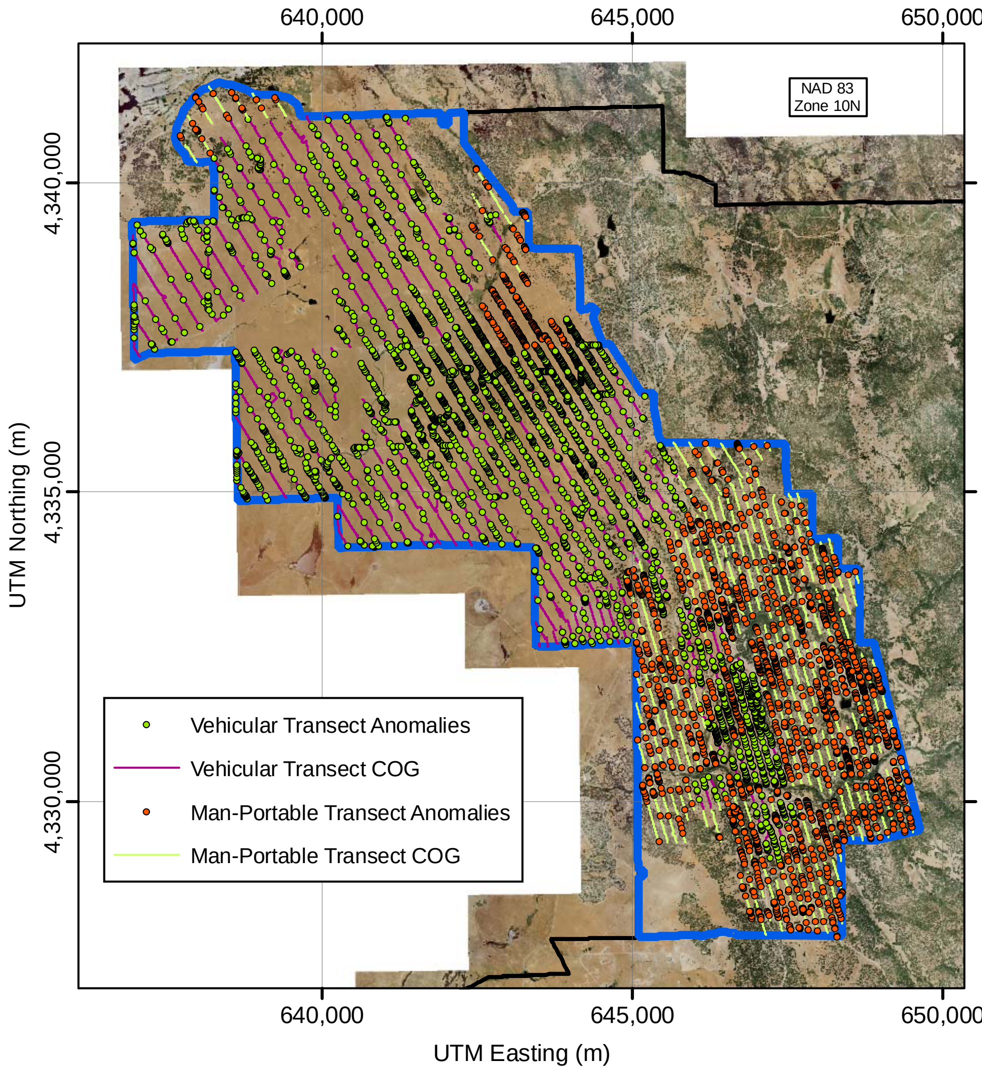

Figure 3-9 – Map showing the transect survey results for the Former Camp Beale demonstration. Vehicular transect COGs are shown as magenta lines and individual detected anomalies are shown as green-filled circles. Man-portable transect COGs are shown as green lines and individual detected anomalies are shown as red-filled circles.

Table 3-10 – Excerpt of Annotated Listing of Towed-Array Transect Surveys Conducted During the Former Camp Beale Demonstration

Date / Survey Code	Survey Description	Transect Length (km)	Number of Anomalies Picked
Mortar Transect Area:			
Tuesday 22 May 2007		**12.2**	**500**
'07142004	M32 & M31	2.5	133
'07142005	M31 & M30 & M29	3.2	128
'07142006	M28	0.3	11
'07142007	M33	0.7	25
'07142008	M33	1.5	109
'07142010	M33 & M32 & M31 & M30 & M29	3.9	94
Wednesday 23 May 2007		**12.4**	**387**
'07143003	M26 & M25 & M24 & M23	1.8	21
'07143004	M27 & M28 & M29 & M30	3.0	188
'07143005	M30 & M31	0.7	11
'07143006	M28 & M27 & M26	4.3	83
'07143007	M24 & M25 & M26	2.5	84
Friday 8 June 2007		**4.0**	**31**
07159010	M1	0.2	0
07159011	M3	0.3	0
07159012	M5	0.4	9
07159013	M8	0.4	4
07159014	M10	0.5	6
07159015	M12	0.6	6
07159016	M14	0.7	3
07159017	M16	0.8	3
Tuesday 12 June 2007		**3.6**	**53**
'07163004	M18	0.9	11
'07163005	M20	1.0	13
'07163006	M21	1.1	15
'07163007	M22	0.6	14
Projectile Transect Area:			
Thursday 24 May 2007		**9.1**	**218**
'07144005	P17 & P18 & P19 & P20 & P21 & P22	4.4	80
'07144006	P22 & P23 & P24 & P25 & P26	2.9	121
'07144007	P26 & P27	1.8	17
Friday 25 May 2007		**10.3**	**396**
07145003	P28 & P30 & P25 & P24	2.9	87
07145004	P23 & P22 & P21	2.9	141
07145005	P20 & P19	1.3	39
07145006	P19 & P18 & P17	2.7	105
07145007	P16	0.6	24
Monday 28 May 2007		**11.8**	**103**
'07148003	P01	0.8	16
'07148004	P02	1.2	19
'07148005	P03 South	0.6	5
'07148006	P03 North	0.6	6
'07148009	P04	1.3	6
'07148010	P05	1.5	14
'07148013	P06	1.9	9
'07148014	P07	1.9	12
'07148016	P08 North	1.5	6
'07148017	P09 Middle	0.5	10

3.2.6 Total Coverage Results

In addition to the transect surveys covering the breadth of the WAA demonstration area, two small areas (1.2 and 2.2 acres, respectively) were selected for total coverage surveys by the man-portable team. The two areas were selected in cooperation with the ESTCP Program Office to characterize background anomaly densities in areas found to be quiet (low anomaly density) in the transect survey results. These surveys were conducted in the same manner as was used for the Victorville man-portable demonstration [9] with 0.75m lane spacing. Individual data files were assembled into a master database for each area. These data are available on the attached DVD. Anomaly selection was conducted using the same anomaly extraction threshold as was used for the man-portable transects. Based on the experience gained during the ESTCP UXO Discrimination Study in the Spring 2007, [14], no smoothing passes were used in the anomaly extraction process. This insures that anomalies small in magnitude and spatial extent are not lost. As a consequence, it is possible to extract multiple anomalies from a single large magnitude anomaly and to extract the occasional anomaly from a data artifact. The anomaly lists for each area were reviewed by the Data Analyst prior to export. The anomaly lists are available on the attached DVD. The EM61 MkII data and the anomaly lists were then transferred into the UX-Analyze module of Oasis montaj for individual anomaly analysis. Anomaly reports for each area containing the details of the fit results (fit position, depth, size, etc.) are provided on the attached DVD. See Appendix B, Section B.9.2 for the file format details.

Figure 3-10 shows the locations of the two total coverage areas superimposed on an aerial photograph of the Former Camp Beale WAA demonstration site. Table 3-11 contains a summary of the total coverage survey results. Column two lists the number of anomalies extracted by the anomaly extraction method in each area. Column four lists the acreage of each area. Column 3 contains the resultant number of anomalies per acre.

Table 3-11 – Total Coverage Area Result Summary

Area	Number of Anomalies	Anomalies / Acres	Acres
North	5	2.3	2.2
South	22	18.3	1.2

TCArea North is located in the north-western portion of Bomb Area and TCArea South is located in the south-western portion of the mortar area. Both were selected to represent a “quiet” area, or one with a limited number of anomalies, based on the towed-array transect data. The boundaries are listed in Table 3-12. Boundary files (Geosoft .ply files) for each area are also included on the attached DVD. Time gate 1 anomaly maps for TCArea North and South are shown in Figure 3-11 and Figure 3-12, respectively.

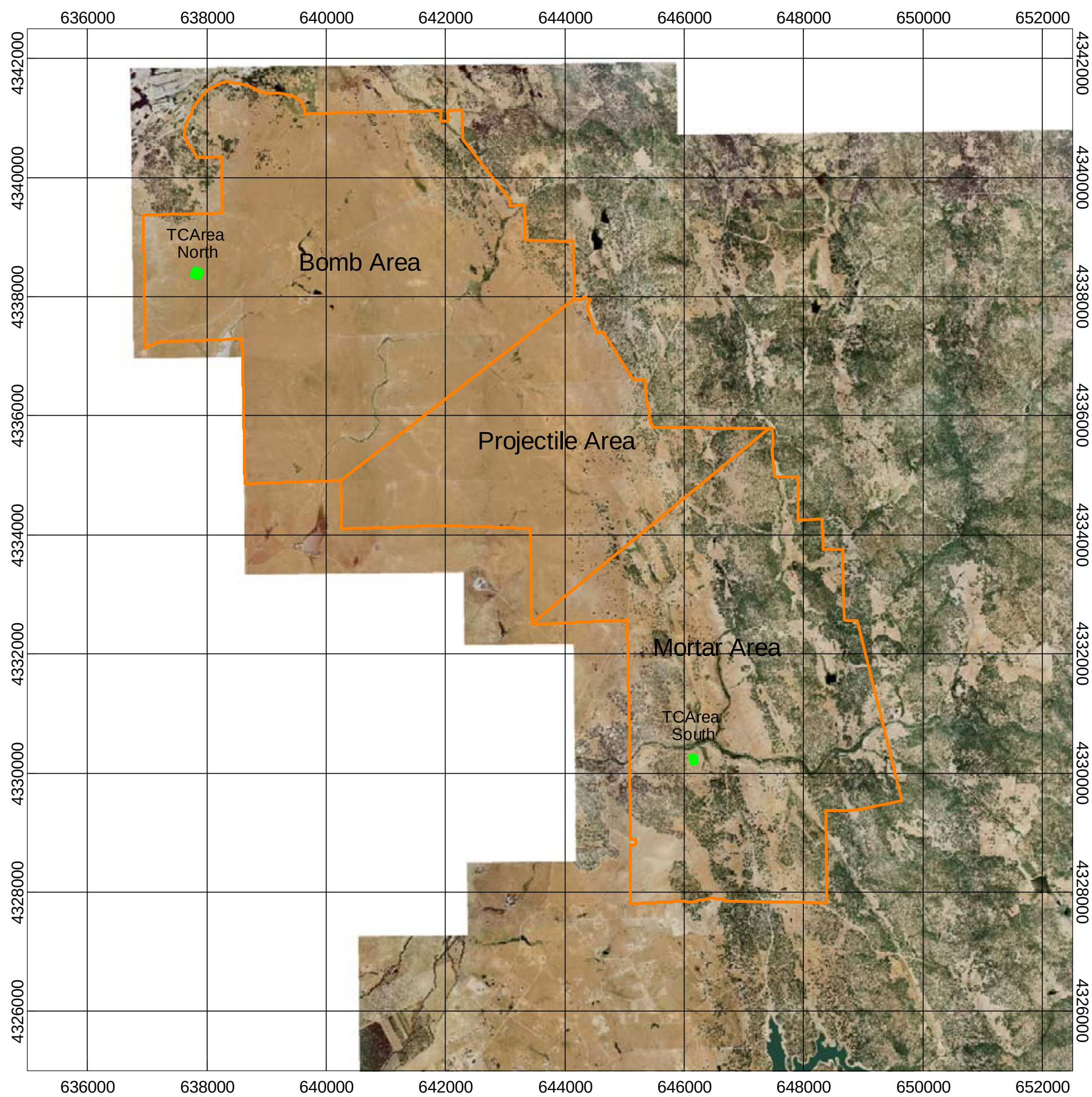

Figure 3-10 – Former Camp Beale Total Coverage Survey Areas

Table 3-12 – Total Coverage Area Boundaries

TCArea North		**TCArea South**	
Easting (UTM, m)	**Northing (UTM, m)**	**Easting (UTM, m)**	**Northing (UTM, m)**
Western Segment		646,116.67	4,330,270.33
637767.00	4,338,362.69	646,171.94	4,330,279.97
637803.55	4,338,349.29	646,186.17	4,330,200.18
637818.93	4,338,384.68	646,189.11	4,330,179.91
637827.70	4,338,407.51	646,134.01	4,330,170.10
637832.99	4,338,422.23		
637,839.77	4,338,443.23		
637,801.07	4,338,454.64		
637,792.47	4,338,431.66		
637,781.88	4,338,404.04		
637,766.17	4,338,362.69		
Eastern Segment			
637,814.96	4,338,346.48		
637,861.93	4,338,328.45		
637,898.98	4,338,423.88		
637,850.85	4,338,439.59		
637,848.54	4,338,431.32		
637,829.85	4,338,381.70		
637,824.22	4,338,366.49		

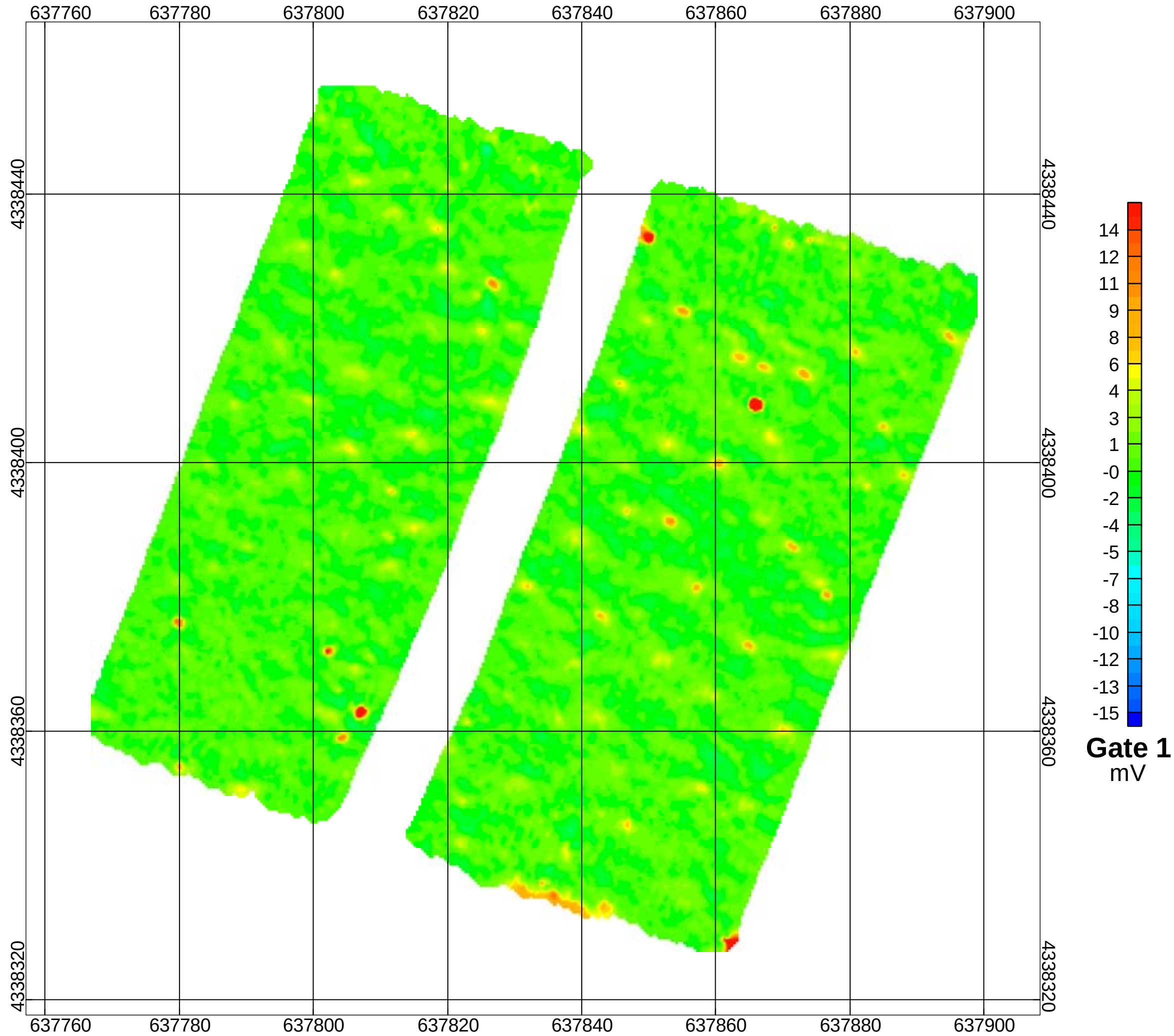

Figure 3-11 – TCArea North EM anomaly map (time gate 1)

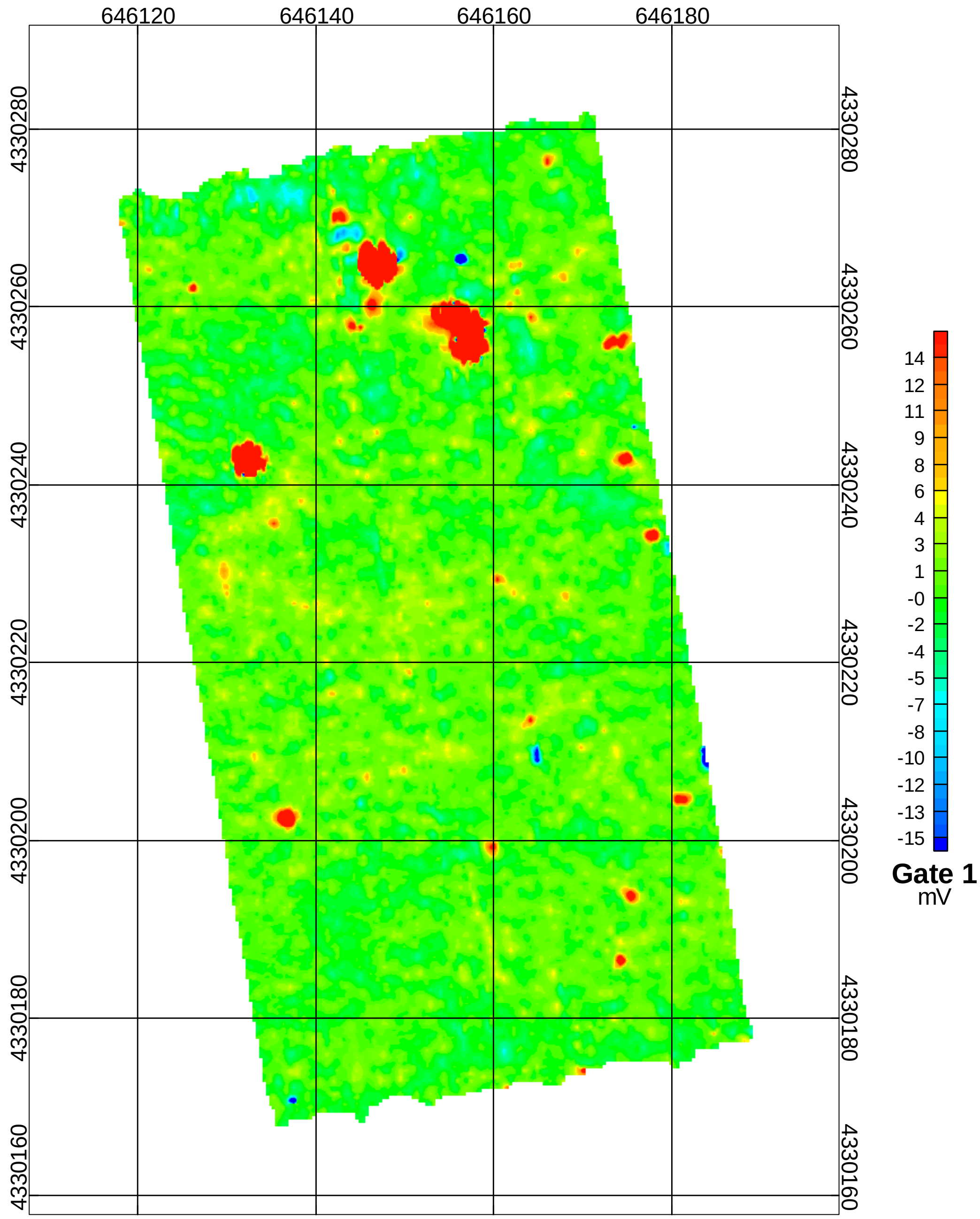

Figure 3-12 – TCArea South EM anomaly map (time gate 1)

3.2.7 Calibration Results

As mentioned in Section 3.2.1, an important piece in maintaining the defensibility of the data collected as part of this demonstration is the daily collection of data to verify the operational nature (e.g. system noise floor) of the sensor systems and to track the reproducibility of the responses from standard items. The same general procedures were followed on a daily basis for the MTADS EM61 MkII Array and the MP EM system. An analysis of the daily performance data is presented in the following two sections along with the specific procedures followed by each system. Any differences in protocol were necessitated by the inherent properties of each sensor system and data processing schemes.

Daily operations commenced with a systems warm-up period of 15-30 minutes to allow the EM61 MkII electronics to stabilize. During this period, the GPS network was established, walk-around maintenance inspections were conducted, and the Site Safety Officer conducted the daily safety meeting.

Following the warm-up period, a complete data set was collected for 5-10 minutes with the system stationary, any vehicle engines turned off, and all personnel stationary or removed from the immediate area. These measurements were used to monitor the system stationary sensor noise floor and positioning system variation at rest. Next, the response to a series of standard munitions and munitions simulants was determined using an emplaced calibration lane or an ad hoc calibration lane. A segment of 'quiet' data found to be anomaly free on the scale of the response from the emplaced items was analyzed to determine the background noise floor for dynamic survey measurements. Based on work done as part of the ESTCP UXO Discrimination Study [14], this method of determining the background signal level yields a lower limit on the real background level. In the case of the Discrimination Study, the data collection was focused on total coverage survey data rather than transect data. In this case, the method used was to remove all known (seeded) anomalies from a representative data set, the geophysical prove-out area (GPO), and calculate the average over all of the remaining data. For the Former Camp Beale demonstration, it was not feasible or necessary to collect such dense data and the 'quiet' data segment approach used in the previous MTADS WAA demonstrations [6-9] was used.

3.2.7.1 MTADS EM61 MkII Array

Static tests of the array were conducted each survey day. A data set was collected for approximately 10 minutes while the sensor platform was kept stationary and all team members standing away from the platform. Every effort was made to minimize the movement of personnel and equipment during the data collection. The 2-D position variation was evaluated by computing the standard deviation of both the northing and easting components of the position data for the entire period and combining them as the square root of the sum of the squares. The 3-D position variation was computed in a similar manner by including the vertical component as well. The standard deviation for the demedianed EM61 MkII data from each time gate was computed for each sensor and the arithmetic mean was computed for all data sets. Results are reported for a) each time

gate, b) all time gates and c) only the bottom coil time gates. In occasional cases, an obvious artifact was present in the data (e.g. a team member moved along side the sensor platform unintentionally) and distorting a portion of the static run. In these cases, only the unperturbed data was used. The aggregate average and standard deviation (1σ) of both the positioning and sensor data for all data sets was computed. The results are shown in the following time-series figures. Table 3-13 and Table 3-14 summarize the static test data results. Figure 3-13 and Figure 3-14 show the positioning and EM61 MkII S1 variations for the static tests, respectively.

Table 3-13 – RTK GPS Static Test Data Results

Result Type	Value
2-D Position	5.03 ± 1.19 mm
3-D Position	9.34 ± 2.03 mm

Table 3-14 – MkII Array Static Test Data Results

Result Type	Value
Gate 1	1.16 ± 0.51 mV
Gate 2	1.49 ± 1.19 mV
Gate 3	0.65 ± 0.40 mV
Gate 4	0.49 ± 0.34 mV
Bottom Gates	0.76 ± 0.37 mV
All Gates	0.95 ± 0.55 mV

A lane of emplaced calibration items was to be installed in the general vicinity of the main base camp at this demonstration site, in a similar manner to previous demonstrations. However, initial surveys conducted to find a relatively benign area for the calibration lane were unsuccessful. The background levels recorded by the towed-array sensors were sufficiently high that a sufficiently large area near the base camp could not be located for the calibration lane. A small quiet area was located nearby that was large enough to establish an ad hoc calibration lane using two steel shotputs near the surface. Emplacement of the full calibration lane was deferred pending the identification of a suitable location. When towed-array survey operations shifted from the main base camp, located in the Mortar Area, to the middle connex, located in the Projectile Area, a suitable location was identified. The calibration items were emplaced near the middle connex with the permission of the property owner. The objects were buried in two parallel lines with 10 – 20-m spacing between items. The locations of each item (nose and tail) were recorded using cm-level GPS. Table 3-15 gives the positions of the emplaced items and parameters (i.e. depth and orientation). Figure 3-15 shows an EM61 MkII anomaly map (S1) of the calibration lane. The midpoint positions of the emplaced items, as determined by RTK GPS waypointing, are shown as open circles. The towed-array system operated out of the middle connex for a significant fraction of the demonstration and was able to use the calibration lane during those periods. For survey days when the vehicle was not based out of the middle connex, ad hoc calibration lanes were established using additional steel shotputs.

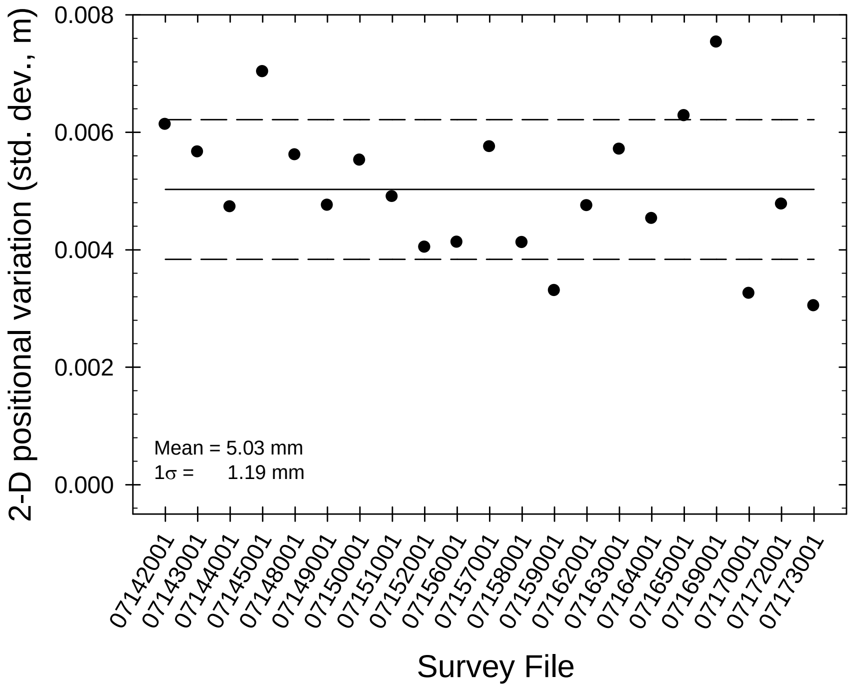

Figure 3-13 – 2-D position variation data runs for stationary data collected with the vehicular towed-array system at the Former Camp Beale WAA site. The horizontal axis is survey file name. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

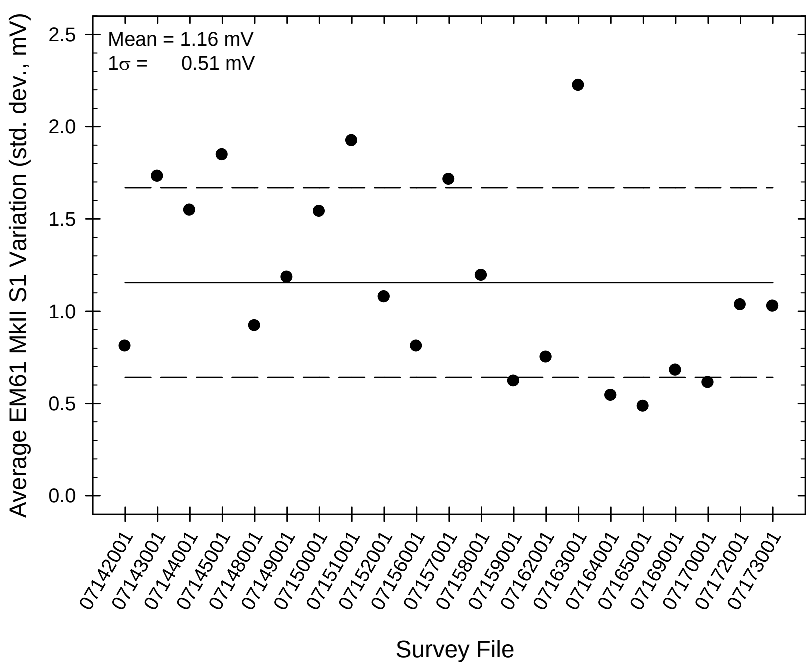

Figure 3-14 – Overall variation of MTADS EM61 MkII array (S1) for daily stationary data collection. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope.

Table 3-15 – Emplaced Items in Former Camp Beale Calibration Strip

Item	Northing (m)	Easting (m)	HAE (m)	Depth (cm)	Orientation (deg)	Length (m)	Avg. Signal (S1 mV)	Std. Dev (S1 mV, 1σ)
155mm Projectile #1	645,330.073	4,335,892.963	145.318	100	18	0.810	280.70	15.75
155mm Projectile #2	645,320.921	4,335,889.461	145.150	65	24	0.803	1053.11	48.47
37mm Simulant #1	645,315.256	4,335,887.374	145.419	10	23	0.108	240.22	19.26
37mm Simulant #2	645,309.660	4,335,885.322	144.886	32	Vertical	0.127	212.81	14.91
60mm Mortar #1	645,303.916	4,335,883.213	144.590	10	10	0.245	396.45	23.16
60mm Mortar #2	645,298.333	4,335,881.212	144.256	28	102	0.220	158.22	13.79
81mm Mortar #1	645,292.783	4,335,879.174	143.885	25	107	0.442	418.67	24.23
81mm Mortar #2	645,285.533	4,335,876.507	143.282	40	26	0.449	236.74	14.15
105mm Projectile #1	645,272.213	4,335,871.678	142.273	40	20	0.614	714.94	34.15
105mm Projectile #2	645,261.316	4,335,868.193	141.530	60	105	0.604	399.52	19.84
Sphere #1	645,333.280	4,335,884.592	145.734	25	N/A	N/A	1020.24	101.91
Sphere #2	645,321.768	4,335,880.479	144.940	25	N/A	N/A	979.72	108.29
Background (1σ)	-	-	-	-	-	-	9.87	0.68

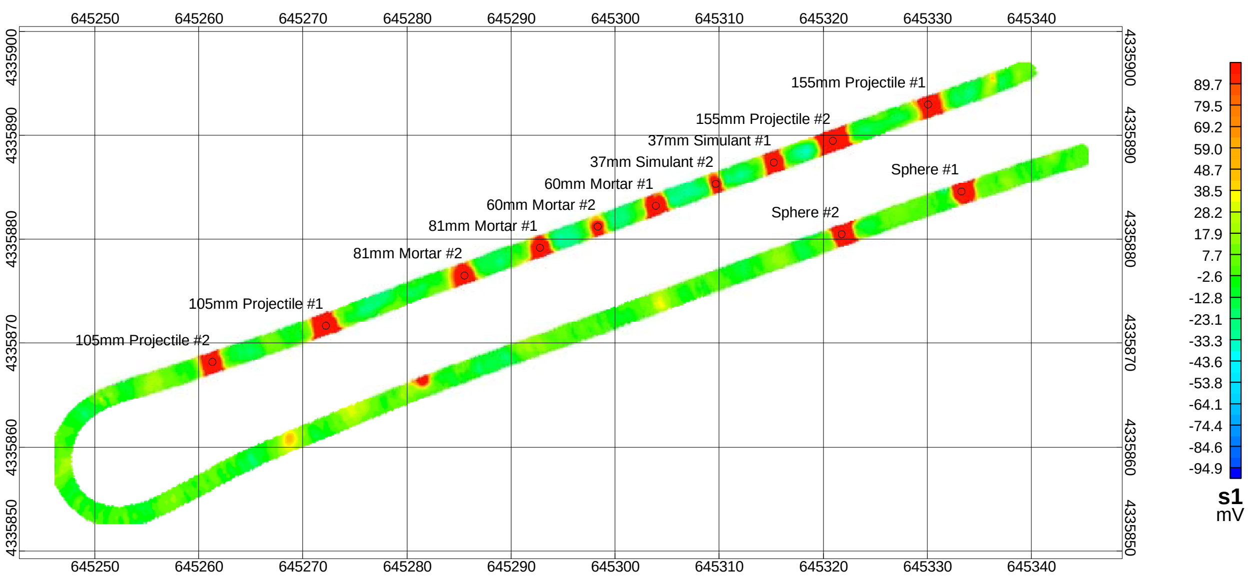

Figure 3-15 – EM61 MkII anomaly map (S1) of the calibration strip emplaced near the middle connex within the Projectile Area at the Former Camp Beale Demonstration Site. Data are from Julian Date 07170 (07170011).

Figure 3-16 plots the peak EM61 MkII (S1) sensor values for 155mm Projectile #2, one of the emplaced items in the calibration lane, representing the upper bound of anomaly responses. The peak amplitudes corresponding to 155mm Projectile #2 are plotted as a time series indexed by data file. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope. Figure 3-17 plots the peak EM61 MkII (S1) sensor values for 81mm Mortar #2, one of the emplaced items in the calibration lane, representing the lower bound of anomaly responses. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope.

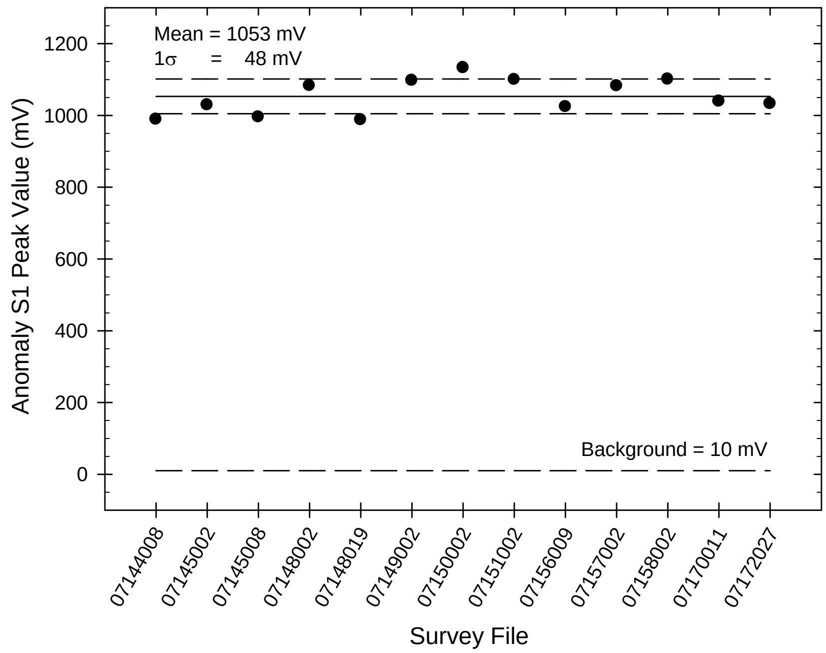

Figure 3-16 – Variation of the EM61 MkII array system (S1) for 155mm Projectile #2. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope. The lower dashed line represents the average background level for the calibration lane.

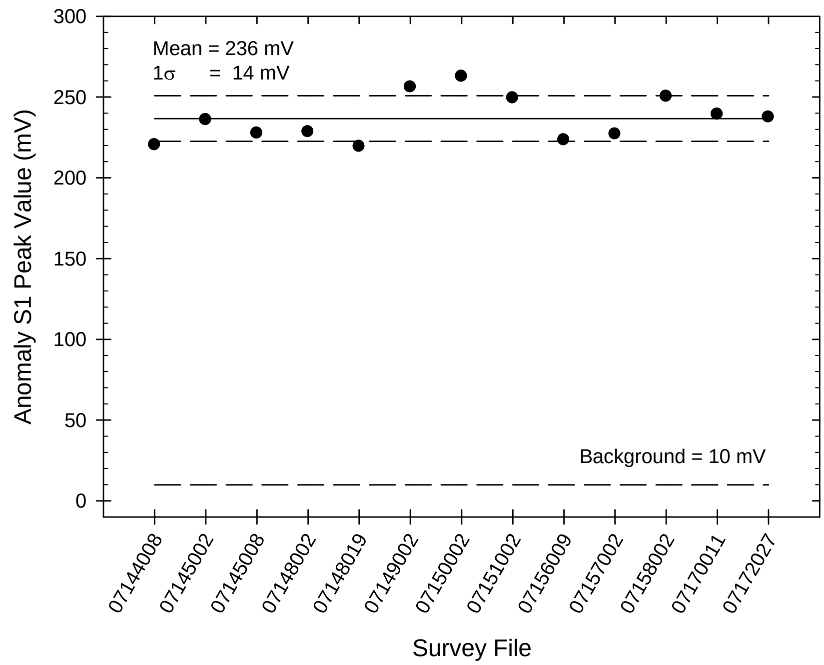

Figure 3-17 – Variation of the EM61 MkII array system (S1) for 81mm Mortar #2. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope. The lower dashed line represents the average background level for the calibration lane.

3.2.7.2 Man-portable EM61 MkII System

Most of the MP EM system data collection effort was focused on the Mortar Area and therefore the MP EM system was typically mobilized out of the main base camp. A calibration lane comprised of a set of 4”- and a 3”-diameter Al spheres was established at the base camp to use as a calibration lane for daily systems checks. When the MP EM system was not staged out of the main base camp, ad hoc calibration lanes were established using steel shotputs. Static tests of the array were conducted each survey day. A data set was collected for approximately 5 minutes while the sensor platform was kept stationary and all team members standing away from the platform. Every effort was made to minimize the movement of personnel and equipment during the data collection. Two different GPS receivers were used for the MP EM system. Initially, the Trimble MS750 cm-level receiver was used to survey the open areas. This is the same receiver type used in the MTADS vehicle and offers the same position accuracy. A Trimble AG-132 sub-meter receiver was then deployed for work under the tree canopy. The AG-132 is a code-only DGPS receiver that has been previously demonstrated to provide significantly better performance under tree canopies than RTK receivers, but at the cost of reduced position accuracy. Position variations were calculated for each system separately. EM61 MkII results are given for all data sets as the EM sensor subsystem did not change. The 2-D position variation was evaluated by computing the standard deviation of both the northing and easting components of the position data for the entire period and combining them as the square root of the sum of the squares. The 3-D position variation was computed in a similar manner by including the vertical component as well. The standard deviation for the demedianed EM61 MkII data from each time gate was computed for each sensor and the arithmetic mean was computed for all data sets. Results are reported for a) each time gate, b) all time gates and c) only the bottom coil time gates. In occasional cases, an obvious artifact was present in the data (e.g. a team member moved along side the sensor platform accidentally) and distorting a portion of the static run. In these cases, only the unperturbed data was used. The aggregate average and standard deviation (1σ) of both the positioning and sensor data for all data sets was computed. The results are shown in the following time-series figures. Table 3-16 and Table 3-17 summarize the static test data results. Figure 3-18 presents the position variation for the cm-level GPS configuration. Figure 3-19 given the results for the sub-meter GPS configuration. Figure 3-20 presents the EM61 MkII variation for the first time gate (S1) for each day.

Table 3-16 – MP GPS Static Test Data Results

Result Type	Value
cm-level RTK	
2-D Position	12.10 ± 6.31 mm
3-D Position	15.54 ± 6.19 mm
Sub-meter DGPS	
2-D Position	21.1 ± 17.3 cm
3-D Position	38.4 ± 21.6 cm

Table 3-17 – MP EM61 MkII Static Test Data Results

Result Type	Value
Gate 1	0.21 ± 0.07 mV
Gate 2	0.14 ± 0.04 mV
Gate 3	0.10 ± 0.02 mV
Gate 4	0.21 ± 0.05 mV
Bottom Gates	0.17 ± 0.04 mV
All Gates	0.15 ± 0.04 mV

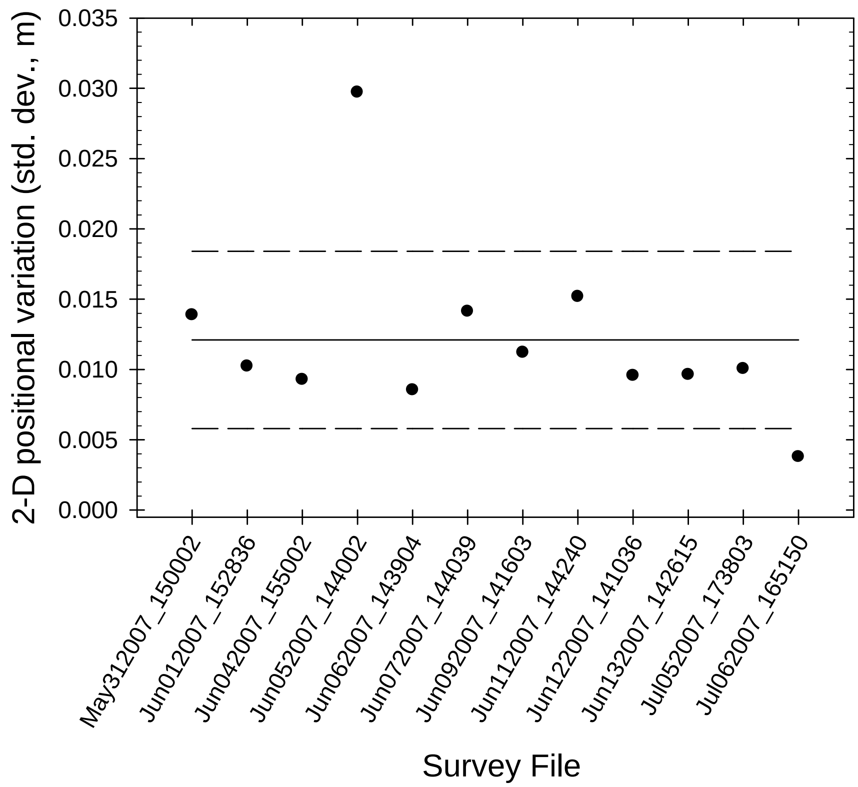

Figure 3-18 – Overall 2-D position variation for the MP EM system at the Former Camp Beale WAA site using cm-level GPS (RTK). The horizontal axis is survey file name. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

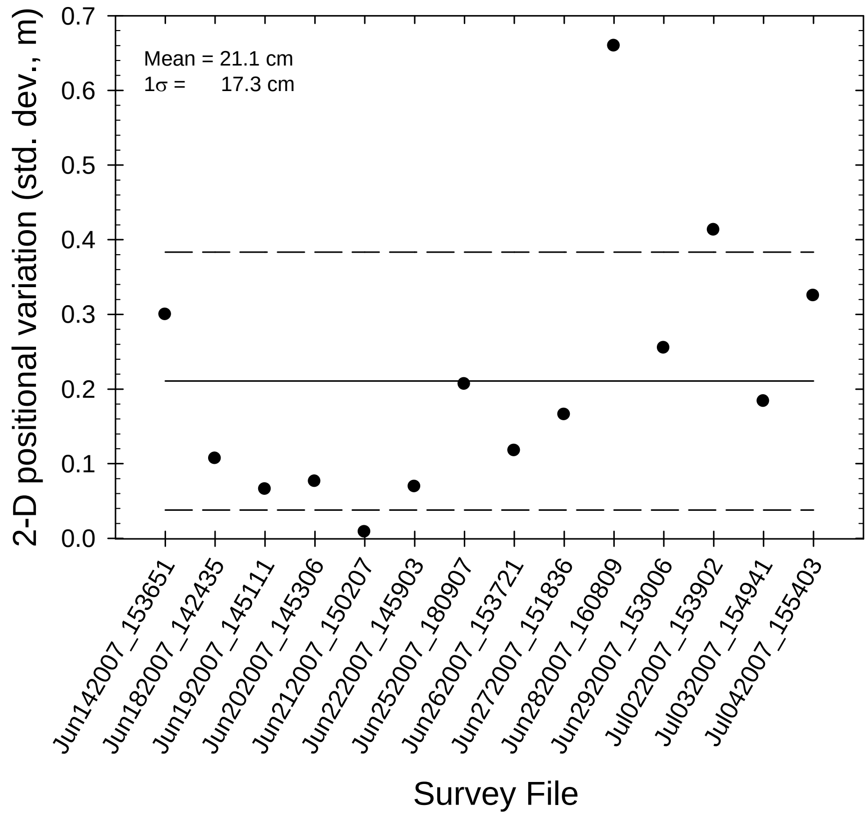

Figure 3-19 – Overall 2-D position variation for the MP EM system at the Former Camp Beale WAA site using sub-meter GPS (DGPS). The horizontal axis is survey file name. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

After the static data collection was completed, a single-pass survey was conducted of the calibration lane in standard survey configuration. To evaluate the data from the calibration items, the peak demedianed sensor value for each time gate was determined for each item. The peak positive value was extracting using the same anomaly extraction technique as for the transect surveys. The results for each survey of the calibration spheres (average and standard deviation (1σ)) are tabulated in Table 3-18. Additionally, a dynamic background value is extracted from the quiet area in between spheres for the main base camp calibration lane. When an anomaly was present in between the shotputs for an ad hoc calibration lane, an appropriate section on either side of the spheres was selected. The dynamic background values are also catalogued in Table 3-18.

Table 3-18 – Peak Demedianed EM Values for the Aluminum Calibration Spheres

Item	**Average Signal (S1 mV)**	**Standard Deviation (S1 mV, 1σ)**
Sphere #1	61.14	11.07
Sphere #2	16.56	2.68
Background (1σ)	1.88	0.35

Figure 3-21 plots the peak EM61 MkII (S1) sensor values for Sphere #1, the 4”-diameter Al sphere emplaced at a depth of 25 cm in the main base camp calibration lane. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope. Figure 3-22 plots the peak EM61 MkII (S1) sensor values for Sphere #2, the 3”-diameter Al sphere emplaced at a depth of 25 cm in the main base camp calibration lane. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope.

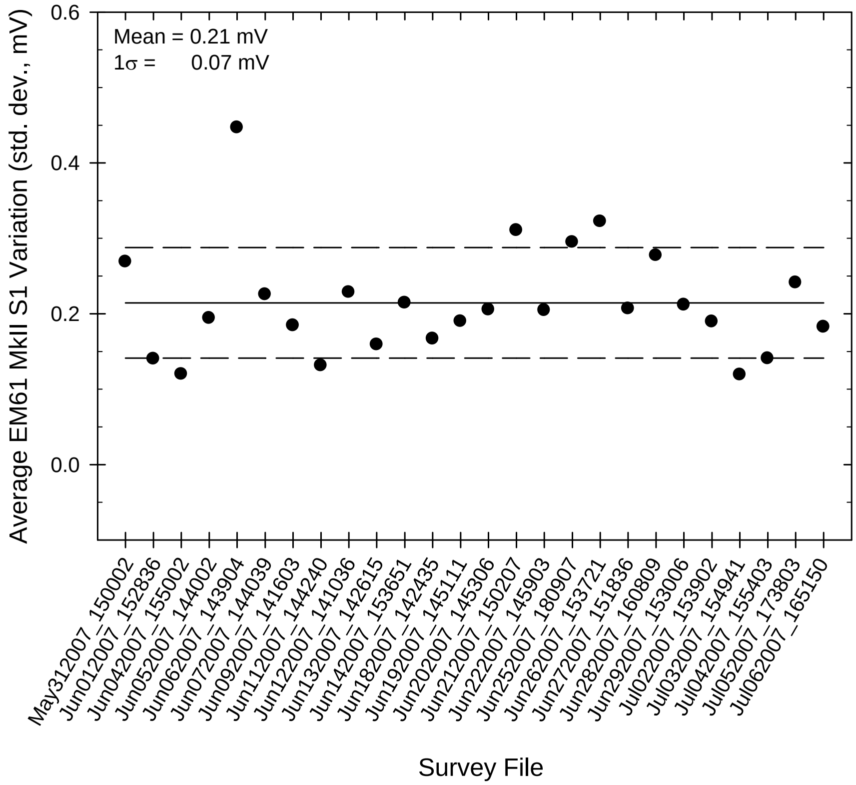

Figure 3-20 – Overall variation of the MP EM61 MkII system (S1). The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope.

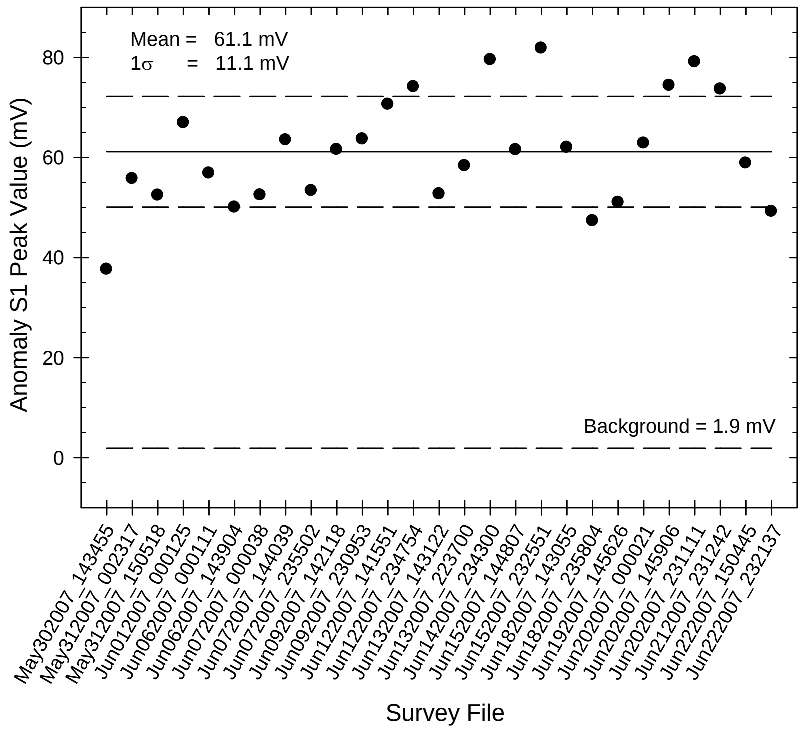

Figure 3-21 – Overall variation of the MP EM61 MkII system (S1) Sphere #1, the 4”-diameter Al sphere emplaced at a depth of 25 cm in the main base camp calibration lane. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope. The lower dashed line represents the average background level for the calibration lane.

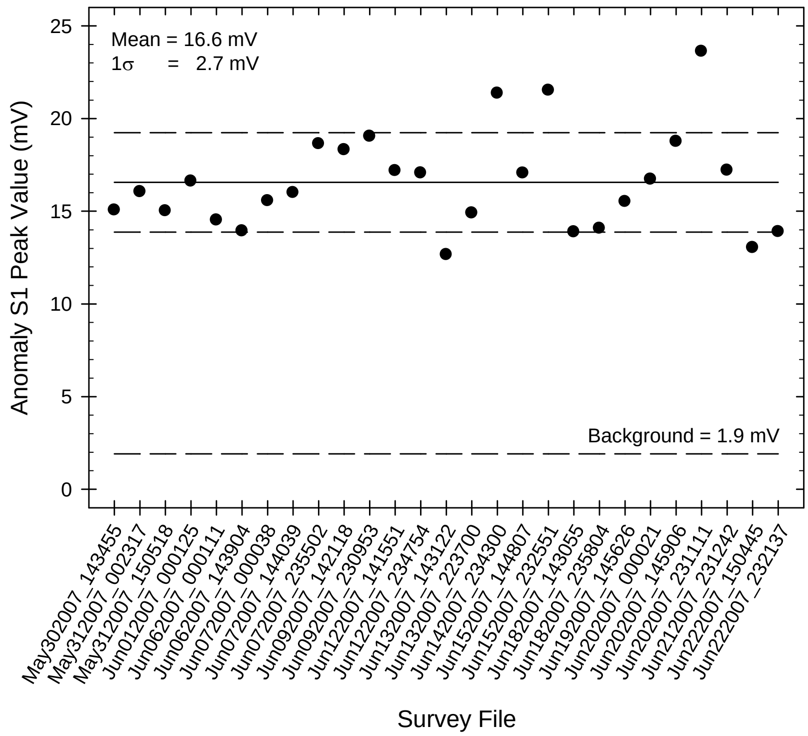

Figure 3-22 – Overall variation of the MP EM61 MkII system (S1) for Sphere #2, the 3"-diameter Al sphere emplaced at a depth of 25 cm in the main base camp calibration lane. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope. The lower dashed line represents the average background level for the calibration lane.

3.2.8 Demobilization

At the end of field vehicular operations, all equipment, materials, and supplies not required for the continuing man-portable demonstration were repacked on the 53' trailer and secured. Harris Transportation, a government contract transportation firm transported the trailer from the demonstration site to Blossom Point, MD. The local vendors were contacted to remove the trailers and generators prior to personnel departing the site. The man-portable team packed and shipped their equipment to Blossom Point via a conventional shipper, FedEx, at the completion of the man-portable demonstration.

3.2.9 Health and Safety Plan (HASP)

The Health and Safety Plan (HASP) for this demonstration is provided in Appendix D: MTADS Safety, Health, and Emergency Response Plan of the Demonstration Plan [16]. This HASP is the standard stand-alone MTADS Safety, Health, and Emergency Response Plan (SHERP) updated with site-specific information (e.g., hospital location) as there is no host facility.

3.3 Management and Staffing

The responsibilities for this demonstration are outlined in Figure 3-23. Dr. Daniel Steinhurst was the PI of this project and filled the roles of Site / Project Supervisor and Quality Assurance Officer. Mr. Glenn Harbaugh of Nova Research, Inc. and Mr. Jay Johnson of EOTI, Inc shared the position of Site Safety Officer. NAEVA Geophysics was responsible for field operations and data collection. Drs. Nagi Khadr and Tom Bell and Mr. Tom Furuya, of SAIC, Inc. were the Data Analysts for this effort.

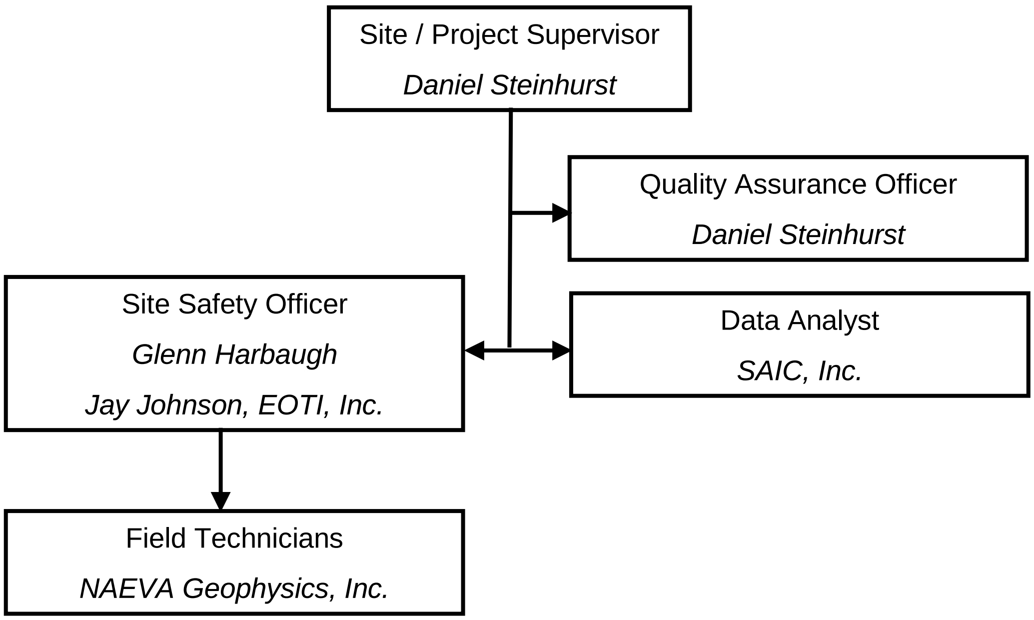

Figure 3-23 – Management and Staffing Wiring Diagram

4. References

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8. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Victorville Precision Bombing Ranges Y and 15, Demonstration Data Report," G.R. Harbaugh, D.A. Steinhurst, N. Khadr, Nova Technical Report NOVA-2031-TR-0002, October 3, 2006.

9. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Man-Portable EM Demonstration Data Report, Victorville Precision Bombing Ranges Y and 15," G.R. Harbaugh, and D.A. Steinhurst, Accepted by ESTCP on December 12, 2006.

10. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Pueblo Precision Bombing and Pattern Gunnery Range #2, La Junta, CO and Victorville Precision Bombing Ranges Y and 15 Victorville, CA," G.R. Harbaugh, D.A. Steinhurst, N. Khadr, accepted by the ESTCP Program Office on June 29, 2007.

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17. Undated, untitled document containing the current proposed Former Camp Beale Transect plan received the week of April 23rd from the WAA Pilot Project Manager.

5. Points of Contact

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Appendix A. MTADS EM61 MkII Performance at the Standardized UXO Technology Demonstration Sites

The Chemistry Division of the Naval Research Laboratory has participated in several programs funded by SERDP and ESTCP whose goal has been to enhance the discrimination ability of MTADS for both the magnetometer and EM-61 array configurations. The process was based on making use of both the location information inherent in an item's magnetometry response and the shape and size information inherent in the response to the time-domain electromagnetic induction (EMI) sensors that are part of the baseline MTADS in either a cooperative or joint inversion. As part of ESTCP Project 199812, a demonstration was conducted on a live-fire range, the 'L' Range at the Army Research Laboratory's Blossom Point Facility [11]. In 2001, a second demonstration was conducted at the Impact Area of the Badlands Bombing Range, SD [12] as part of ESTCP Project 4003. In all these efforts, our classification ability has been limited by the information available from the time-domain EMI sensor. The EM61 is a time-domain instrument with either a single gate to sample the amplitude of the decaying signal (MkI) or four gates relatively early in time (MkII). The first generation of the MTADS EM61 MkII array was demonstrated in 2001 [12] at the Badlands Bombing Range, SD with little demonstrable gain over the single decay of the MkI array. A second generation of the MkII array with updated electronics was constructed in 2003 as part of ESTCP Project 200413.

The upgraded MTADS EM61 MkII array was demonstrated at both of the Standardized UXO Technology Demonstration Sites located at the Aberdeen and Yuma Test Centers in 2003 and 2004 [13]. At each of the sites, the Calibration Lanes, the Blind Test Grid (if available), and as much of the Open Field Area as was possible were surveyed. The scoring results are the basis for characterizing the success of the demonstrations and the performance of the array. The Open Field results are presented here to demonstrate the performance of the MTADS EM61 MkII Array.

A.1 Aberdeen Proving Ground Open Field

Selected results from our surveys at the Open Field at the Aberdeen Proving Ground Standardized Test Site have been provided to us by analysts at the Institute for Defense Analyses. These results are summarized graphically in the following sections.

A.1.1 Response Stage

Response stage results for the APG Open Field scenario are shown in Figure A-1and Figure A-2. The results are analyzed by excluding first items that were not covered by the survey or are within 2-m of another item then retaining those exclusions and further excluding items deeper than 11x their diameter.

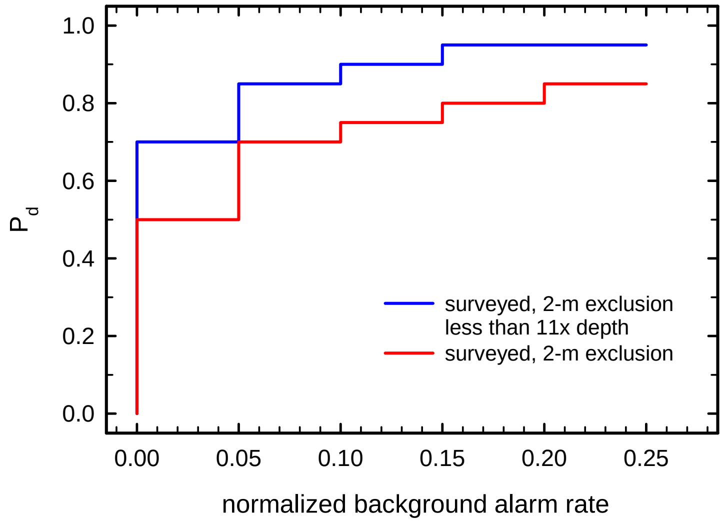

Figure A-1 – MTADS EM61 MkII detection performance at the APG Open Field Scenario. The red line is derived considering only targets that were covered in the survey and are not within 2 m of another target. The blue line retains those criteria and also excludes targets deeper than 11x their diameter.

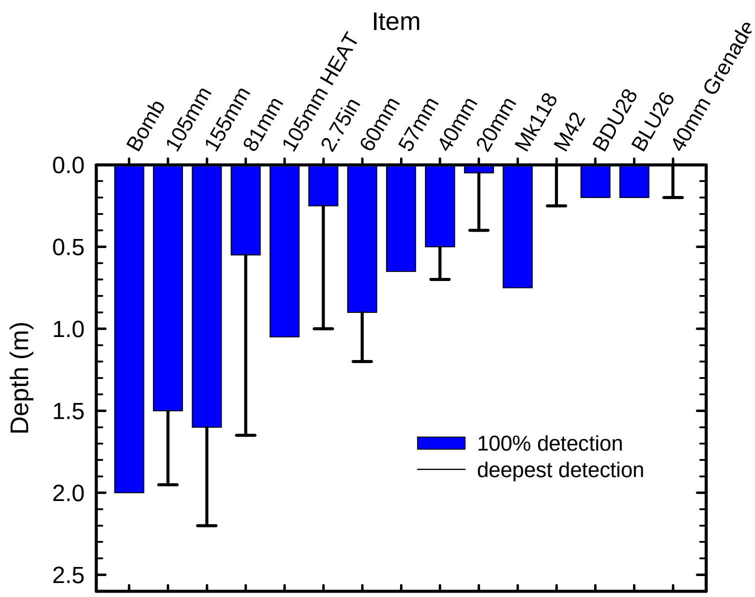

Figure A-2 – MTADS EM61 MkII response stage results for the APG Open Field scenario broken out by target type

A.1.2 Discrimination Stage

Discrimination Stage results from the APG Open Field are shown in Figure A-3. Exclusion of items that are deeper than 11x their diameter improves performance.

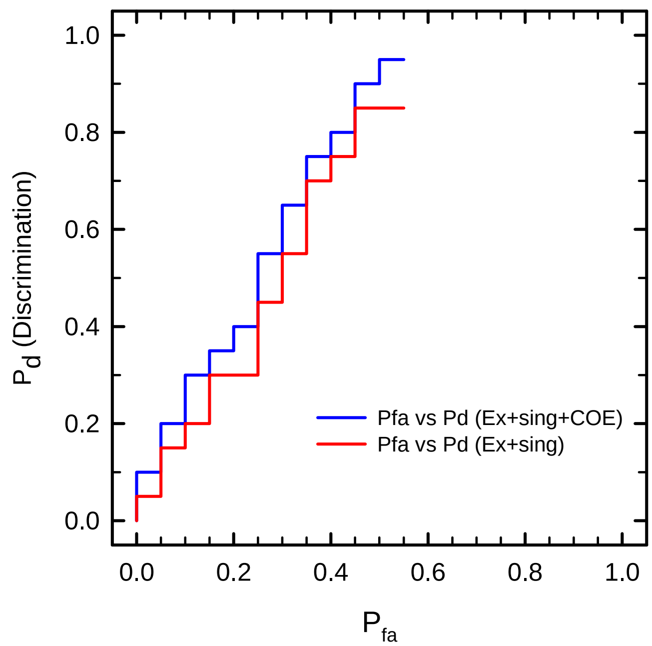

Figure A-3 – MTADS EM61 MkII discrimination performance at the APG Open Field Scenario. The red line is derived considering only targets that were covered in the survey and are not within 2 m of another target. The blue line retains those criteria and also excludes targets deeper than 11x their diameter.

Appendix B. Quality Assurance Project Plan (QAPP)

B.1 Purpose and Scope of the Plan

The collection and archiving of high quality survey data in auditable and defensible manner is critical to insure the credibility of the data collected and to support decisions based in part or in total on that data. This Appendix outlines the standard process used in the NRL MTADS program to collect survey data, conduct quality checks to insure the quality of the data, and then process and archive the data. With the exception of Section B.9, the discussion focuses on the MTADS magnetometer array system. For the EM61 MkII towed-array and man-portable sensor systems, similar procedures are used, different only in the details of the data collected for each sensor system. Any sensor platform unique items are indicated where appropriate.

B.2 Quality Assurance Responsibilities

The team as a whole is involved in ensuring the quality of collected data. The MTADS has been designed to provide a series of visual indicators to the operator regarding the status of the individual subsystems that comprise the MTADS. The operator is responsible for monitoring these indicators and halting data collection immediately if any problems are indicated. The issue will be resolved prior to resuming operations. All team members are involved in visual walk-around inspections of the system at least daily. For each survey file set, the data preprocessing tasks are logging receipt of the file set, archiving the file set, verifying that all files within the file set are valid, and verifying that each sensor channel contains valid data with sufficient SNR (where appropriate). Any section of data which is found lacking is flagged accordingly and not processed any further. The section will be logged for future re-acquisition if necessary. After these checks are completed, the resultant located survey data is submitted to the automated anomaly picking routines for analysis and anomaly report generation. The data analyst is responsible for the data preprocessing and processing tasks with the site / project manager's assistance as available. Dr. Daniel Steinhurst will serve as the Quality Assurance Officer for this project.

B.3 Data Quality Parameters

Incoming survey data will be evaluated for: completeness of the data set, location (GPS) quality for the data set, and for proper operation of the geophysical sensors. The following section details in an example how the data quality issues are addressed throughout the survey.

B.4 Calibration Procedures, Quality Control Checks, and Corrective Action

The following procedure constitutes a typical startup for the MTADS system for both initial startup and as daily system evaluations. The RTK GPS base station receiver and radio link will be established on one of the established control points. The validity of the control point location will be verified using the MTADS man-portable RTK GPS rover receiver to occupy one or more of the established control points using the control point occupied by the GPS base station as a reference as required by the QAO.

For EM61 MkII platforms, the standard performance checks conducted during initial system setup at the beginning of field work and again each morning of field work consists of two measurements. First, quiet, static data is collected for a period (5-10 minutes or as directed by the QAO) with all systems powered up and warmed up (typically 30 minutes). Next, a survey of the emplaced calibration items will be conducted and repeated at the beginning and end of each work day and as required by the QAO. Data will be digital recorded and submitted to the Data Analyst. The data are checked for appropriate signal strength and noise levels immediately. When all systems checks are completed to the satisfaction of the QAO, the main survey will commence.

Preventative maintenance inspections will be conducted at least once a day by all team members, focusing particularly on the tow vehicle and sensor platforms. Any deficiencies will be addressed according to the severity of the deficiency. Parts, tools, and materials for many maintenance scenarios are available in the system spares inventory which will be on site. Status on any break-downs / failures which will result in long-term delays in surveying will be immediately reported to the WAA Project Manager.

MTADS survey raw data generally falls into two categories, location (GPS) and geophysical sensor measurements. The data set is comprised of several separate files, each containing the data from a single system device. Each device has a unique data rate. A software package written by NRL examines each file and compares the number of entries to the product (total survey time * data rate). Any discrepancies are flagged for the data analyst to address. For magnetometer sensor data, operational values are typically on the order of 50,000 nT and have noise levels of ~0.5 nT peak-to-peak (PP) static and 3-5 nT PP in motion. Sensor "drop-outs" can occur if the sensor is tilted out of the operation zone with respect to the earth's magnetic field. If a sensor cable is severed or damaged while in motion, the sensor output value will drop below 20,000 nT and/or become very noisy (1,000's of nT PP). All magnetometer sensor channels (8 total) are examined in each survey file set for these conditions and any data which is deemed unsatisfactory is flagged and not processed further. For location data, the RTK GPS receivers present a Fix Quality value that relates to the quality / precision of the reported position. A Fix Quality (FQ) value of 3 (RTK Fixed) is the best accuracy (typically 3-5 cm or better). A FQ value of 2 (RTK Float) indicates that the highest level of RTK has not be reached yet and location accuracy can be degraded to as poor as ~1 m. FQ 1 & 4 are Autonomous and DGPS respectively. Data collected under FQ 3 and FQ 2 (at the discretion of the data analyst) is retained. Any other data is deemed unsatisfactory, flagged and not processed further. Survey section containing flagged data will be logged for future re-acquisition if required. Data which meets these standards is of the quality typical of the MTADS system.

B.5 Demonstration Procedures

See Section B.4. The same discussion applies to this section.

B.6 Calculation of Data Quality Indicators

There are no specialized equations required. The methods are outlined in Section B.4.

B.7 Performance and System Audits

See Section B.4. The same discussion applies to this section.

B.8 Quality Assurance Reports

The results of the daily system checkout runs for the static survey and the dynamic survey of the emplaced items will be reported to the QAO daily. The Data Analyst will report any transect sections requiring reacquisition to the site / project manager for a given day by the start of work the following morning.

B.9 Data Formats

B.9.1 MTADS EM61 MkII Array Data Formats

Each survey file set contains 10 files which constitute the 'raw data'. The file name structure is YYDDDFFF.DeviceType.DeviceAlias; where YY is the 2-digit year, DDD is the "Julian" day, or day in the year, and FFF is the flight number starting with 001. Each data line is time stamped with the PC system clock to allow synchronization between files

YYDDDFFF.Survey.EM61MII.EM61_MkII_1
    Output from Sensor #1 (Port), 4 time gates (counts), Transmit current (counts), and battery voltage (counts).
YYDDDFFF.Survey.EM61MII.EM61_MkII_2
    Output from Sensor #2 (Center), 4 time gates (counts), Transmit current (counts), and battery voltage (counts).
YYDDDFFF.Survey.EM61MII.EM61_MkII_3
    Output from Sensor #3 (Starboard), 4 time gates (counts), Transmit current (counts), and battery voltage (counts).
YYDDDFFF.Survey.GPS.NMEA
    GPS output, Trimble PTNL,GGK sentence at 10 Hz (position).
YYDDDFFF.Survey.LineNumber
    Start and stop time of each line in survey, typically only one line / file
YYDDDFFF.Survey.PpsDevice.PPS
    Pulse per second (PPS) from GPS receiver, 1 Hz.
YYDDDFFF.Survey.SerialDevice.UTC
    UTC time tag from GPS receiver, "The time will be" message for next PPS, 1 Hz.

The .Survey, .Survey.page, and .Survey.loginfo*.txt files are setup information recorded by the data collection program and contain no data of use to the user. The EM61 MkII data file format is a packed binary data formats with an ASCII date/time tag appended to each data packet. The data packet formats are described in the manufacturer's manuals and technical notes and are not reproduced here.

.Survey.GPS.NMEA files:

```
$PTNL,GGK,175017.00,122104,3825.06336634,N,07706.26656042,W,3,07,2.8,EHT-
25.694,M*7C  12/21/04 12:45:39.470
```

Table B-1 – PTNL,GGK Message Fields

Field	Meaning[a]
1	UTC of position fix
2	Date
3	Latitude
4	Direction of Latitude (N = North, S = South)
5	Longitude
6	Direction of Longitude (E = East, W = West)
7	GPS Fix Quality (0 = Invalid,1,2,3,4)
8	Number of Satellites in fix
9	DOP of fix
10	Ellipsoidal height of fix
11	M: ellipsoidal height is measured in meters

[a] For further information, refer to the Trimble MS Series Operation Manual

.Survey.SerialDevice.UTC files:

```
UTC 04.12.21 17:50:18 57  12/21/04 12:45:39.645
UTC 04.12.21 17:50:19 57  12/21/04 12:45:40.646
```

Anomaly Report (.Anomaly) Files:
Anomaly Reports from Transect data will be ASCII files of the format:

```
ID Fiducial ID of the anomaly
X  (UTM Zone X, NAD83, m) Easting
Y  (UTM Zone X, NAD83, m) Northing
S  EM61 MkII Signal in mV (Gate1, initially)
```

where X is the appropriate UTM zone (10N for Marysville, CA)

Course over Ground (.COG) files:
Corresponding Course-Over-Ground (COG) Reports for Transect data will be ASCII files of the format:

```
X       (UTM Zone X, NAD83, m) Easting
Y       (UTM Zone X, NAD83, m) Northing
GPSTime UTC Time in seconds past midnight
```

where X is the appropriate UTM zone (10N for Marysville, CA)

Located, demedianed data archive format for EM61 MkII data is:

```
X          (UTM Zone X, NAD83, m) Easting for the sensor
Y          (UTM Zone X, NAD83, m) Northing for the sensor
HAE        (WGS84, m) Height above Ellipsoid for the sensor
Heading    (degrees) Heading of array in Grid North frame, North = 0 degrees
SensorID   Denotes which sensor the data was recorded from
Gate1      (mV) Demedianed magnetometer data for first gate, bottom coil
Gate2      (mV) Demedianed magnetometer data for first gate, top coil
Gate3      (mV) Demedianed magnetometer data for second gate, bottom coil
Gate4      (mV) Demedianed magnetometer data for third gate, bottom coil
```

where X is the appropriate UTM zone (10N for Marysville, CA)

Static Survey Archive (_static.xyz) files:
Daily static calibration run data will be archived as geosoft .XYZ files of the format:

```
X         (UTM Zone X, NAD83, m) Easting for the GPS antenna
Y         (UTM Zone X, NAD83, m) Northing for the GPS antenna
HAE       (WGS84, m) Height above Ellipsoid for the GPS antenna
SensorID  Denotes which sensor data is from
Gate1     (mV) Demedianed magnetometer data for first gate, bottom coil
Gate2     (mV) Demedianed magnetometer data for first gate, top coil
Gate3     (mV) Demedianed magnetometer data for second gate, bottom coil
Gate4     (mV) Demedianed magnetometer data for third gate, bottom coil
```

where X is the appropriate UTM zone (10N for Marysville, CA)

UX-Analyze Target List Example

The example is given in ASCII text file format. Actual delivery will be in Excel Spreadsheet format.

```
/ ----------------------------------------------------------------------------
---
/ CSV EXPORT [10/18/2006]
/ DATABASE   [c:\montaj~1\waapro~1\waavvm~1\PBR15_Anomalies.gdb]
/ ----------------------------------------------------------------------------
---
/
/fid,Fit_X,Fit_Y,Latitude,Longitude,Fit_Depth,Fit_Size,Fit_Coh,Fit_b1,Fit_b2,
Fit_b3,Fit_theta,Fit_phi,Fit_psi,Fit_chi2,Fit_Error,Comments,Comments_2
Line DAnomalies
0,546367.83,3806177.80,34.395976453,-
116.495551050,1.096,0.081,0.928,3.643,0.542,0.000,83.86,74.77,8.76,0.727,0,""
,""
1,546388.83,3806178.25,34.395979030,-
116.495321551,0.651,0.034,0.658,0.205,0.113,0.000,-
19.93,10.18,72.45,0.428,0,"",""
2,546459.59,3806178.67,34.395975854,-
116.494552376,0.265,0.024,0.921,0.105,0.003,0.000,75.40,48.51,-
7.77,0.550,0,"Partial Anomaly on Edge of Data.",""
3,546413.58,3806179.04,34.395984953,-
116.495049535,0.770,0.061,0.970,1.808,0.021,0.005,81.41,310.50,130.26,1.022,0
,"",""
```

B.9.2 Man-Portable EM61 MkII System Data Formats

Each survey file set contains 4 files which constitute the ‘raw data’. The file name structure is MMMDDYYYY_HHMMSS.DeviceType; where MMM is the 3-letter abbreviation of the month, DD is the date, YYYY is the 4-digit year, HH is the file start time hour in 24-hour format, and MM and SS are the start time minutes and seconds. In the following example, the data was taken on October 8th, 2006 starting at 15:21:49. The PC clock is synced to UTC at program entry.

Oct082006_152149.pps
Oct082006_152149.mark

Oct082006_152149.mkii
Oct082006_152149.nmea

Each data line is time stamped with the PC system clock to allow synchronization between files

MMMDDYYYY_HHMMSS.mkii -	Output from Geonics EM61 MkII (Mode, Scale Factor, 4 channels, Tx current, battery voltage), 10 Hz.
MMMDDYYYY_HHMMSS.pps -	pulse per second (PPS) from GPS receiver, 1 Hz.
MMMDDYYYY_HHMMSS.nmea -	GPS output, Trimble PTNL,GGK sentence at 10 Hz (position) and UTC time tag from GPS receiver, "The time will be" message for next PPS, 1 Hz.
MMMDDYYYY_HHMMSS.mark -	Fiducial markers recorded by operator, if used.

EM61 MkII (.mkii) files:

```
D  FF        -980        697        631        1976      3420   12.75  55309.000  55309.050
D  FF        -980        698        631        1977      3423   12.75  55309.100  55309.150
D  FF        -979        698        629        1976      3414   12.75  55309.200  55309.250
D  FF        -980        698        629        1976      3408   12.75  55309.300  55309.350
D  FF        -980        698        629        1976      3412   12.75  55309.400  55309.450
```

First line:
D – Sensor Mode, ‘D’ is differential (3 gates on bottom coil, 1 gate on top coil), ‘T’ mode has 4 time gates on bottom coil
FF – Scale factor. Hexidecimal representation of range factors for 4 time gates. ‘FF’ corresponds to the highest range (100x) for all four time gates.
Channel 1
`-980 - -980 counts`
Channel 2
`697 - 697 counts`
Channel 3
`631 - 631 counts`
Channel T
`1976 - 1976 counts`
Tx Current
`3420 - 3420 counts`
Battery Voltage
`12.75 – 12.75 VDC`

`55309.000` – PC Time stamp for transmission of trigger character.
`55309.050` - PC Time stamp for receipt of data packet.

.PPS files:

```
55309.990
55310.990
55311.990
```

.NMEA files:

```
$PTNL,GGK,152149.00,100806,3423.76458565,N,11629.97525670,W,3,08,1.8,EHT766.6
92,M*6B  55309.040
```

```
$PTNL,GGK,152149.10,100806,3423.76458579,N,11629.97525721,W,3,08,1.8,EHT766.6
97,M*67  55309.130
UTC 06.10.08 15:21:50 58  55309.200
$PTNL,GGK,152149.20,100806,3423.76458753,N,11629.97525562,W,3,08,1.8,EHT766.6
96,M*6A  55309.230
```

.mark files:

The .mark file has the same file format as the .PPS file.

Located data archives are ASCII files of the format:

For located, (demedianed) EM61 MkII data:

```
PC_Time (UTC, seconds since midnight)
X (UTM Zone X, NAD83, m) Easting
Y (UTM Zone X, NAD83, m) Northing
Z Height Above Ellipsoid (HAE, WGS84, m)
Heading (Referenced to Grid North, degrees)
Gate1_Fin (demedianed, mV)
Gate2_Fin (demedianed, mV)
Gate3_Fin (demedianed, mV)
Gate4_Fin (demedianed, mV)
Gate1_def (not demedianed, mV)
Gate2_def (not demedianed, mV)
Gate3_def (not demedianed, mV)
Gate4_def (not demedianed, mV)
```

where X is the appropriate UTM zone (10N for Marysville, CA)

Course over Ground (.COG) files:
Corresponding Course-Over-Ground (COG) Reports for Transect data will be ASCII files of the format:

```
X       (UTM Zone X, NAD83, m) Easting
Y       (UTM Zone X, NAD83, m) Northing
PCTime  UTC Time in seconds past midnight (also computer time)
```

where X is the appropriate UTM zone (10N for Marysville, CA)

Static Survey Archive (.xyz) files:
Daily static calibration run data will be archived as Geosoft .XYZ files of the format:

```
PC_Time (UTC, seconds since midnight)
X       (UTM Zone X, NAD83, m) Easting for GPS antenna
Y       (UTM Zone X, NAD83, m) Northing for GPS antenna
HAE     (WGS84, m) Height above Ellipsoid for GPS antenna
Gate1_Fin (demedianed, mV)
Gate2_Fin (demedianed, mV)
Gate3_Fin (demedianed, mV)
Gate4_Fin (demedianed, mV)
```

where X is the appropriate UTM zone (10N for Marysville, CA)

UX-Analyze Target List Example

This format is the same as for the towed-array system discussed in the previous section.

B.10 Data Storage and Archiving Procedures

Data is stored electronically as collected on hard drives of the MTADS vehicle DAS computer or the laptop incorporated into the MP EM system. Approximately every two survey hours, the collected data is copied onto removable and transferred to the data analyst. The data is moved onto the data analyst's computer and the media is recycled. Raw data and analysis results are backed up from the data analyst's computer to optical media (CD-R or DVD-R) or external hard disks daily. These results are archived on an internal file server at NRL at the end of the survey. All field notes / activity logs are written in ink and stored in archival laboratory notebooks. These notebooks are archived at NRL. Relevant sections are reproduced in the demonstration reports. Dr. Daniel Steinhurst is the POC for obtaining data and other information. His contact information is provided in Section 5 of this report.

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